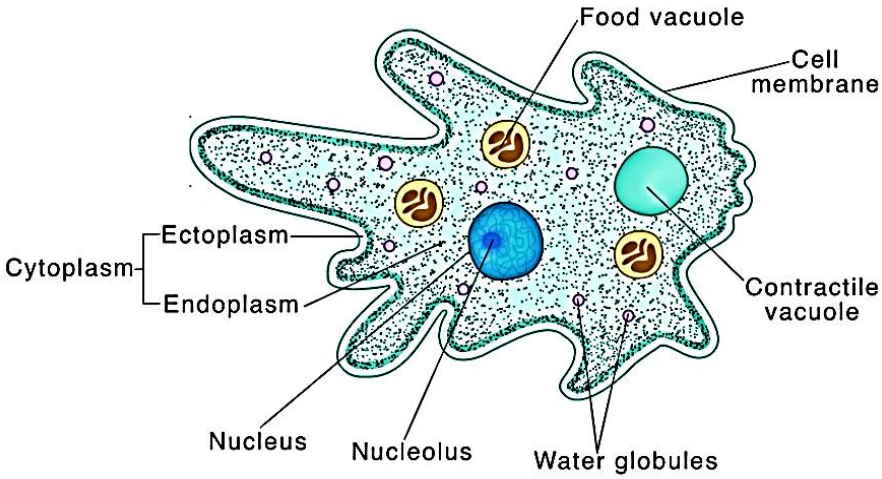
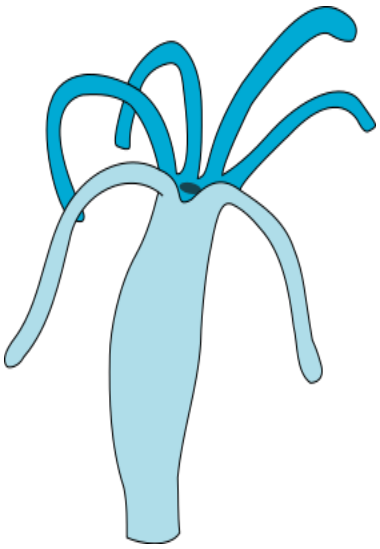
Structural Organisation in animals

INTRODUCTION :

- In **unicellular organisms**, all functions like digestion, respiration and reproduction are performed by a single cell.



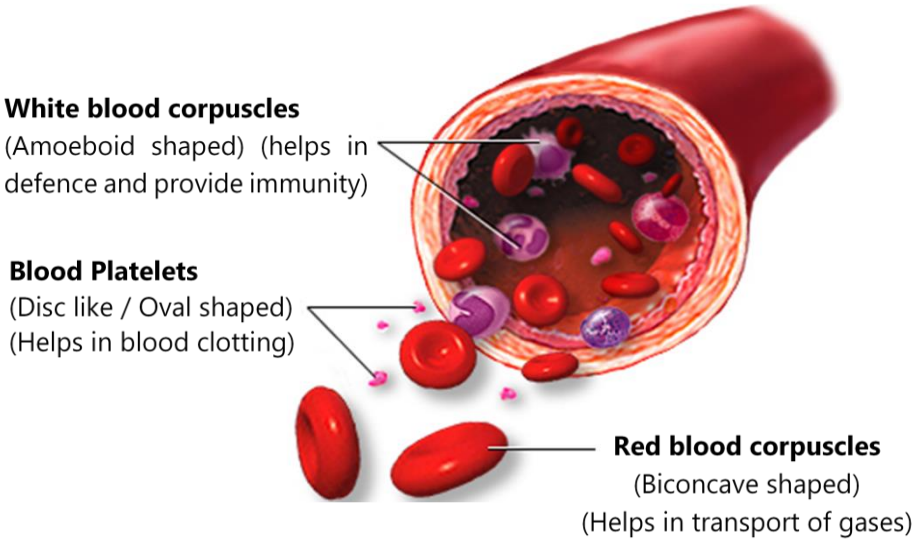
- In the complex body of **multicellular animals** the same basic functions are carried out by different groups of cells in a well organised manner.
- The body of a simple organism like **Hydra** is made of different types of cells and the number of cells in each type can be in thousands.



- The **human body** is composed of billions of cells to perform various functions.
- How do these cells in the body work together?

TISSUE :

- In **multicellular animals**, a group of similar cells along with intercellular substances perform a specific function. Such an organisation is called **tissue**.
- In a tissue, cells may be dissimilar in structure and function but they are always similar in origin.


White blood corpuscles
(Amoeboid shaped) (helps in defence and provide immunity)
Blood Platelets
(Disc like / Oval shaped)
(Helps in blood clotting)
Red blood corpuscles
(Biconcave shaped)
(Helps in transport of gases)

- Blood is a fluid connective tissue and is mesodermal in origin. Blood has two components – plasma and formed elements. Formed elements include RBC, WBC and blood platelets. These formed elements have different shapes and different functions but all are mesodermal in origin.

Question-1: Study of tissue is called –

(1) Histology (2) Herpatology

(3) Chondrology (4) Osteology

Answer: (1) Histology

Question-2: Which of the following is an incorrect statement from the following?

(1) In unicellular organisms, all functions like digestion, respiration and reproduction are performed by a single cell

(2) RBC transport carbon dioxide and oxygen

(3) WBC helps in blood clotting

(4) Blood is mesodermal in origin

Answer: (3) WBC helps in blood clotting

Question-3: Tissues differ from group of cells in –

(1) Function

(2) Division of labour

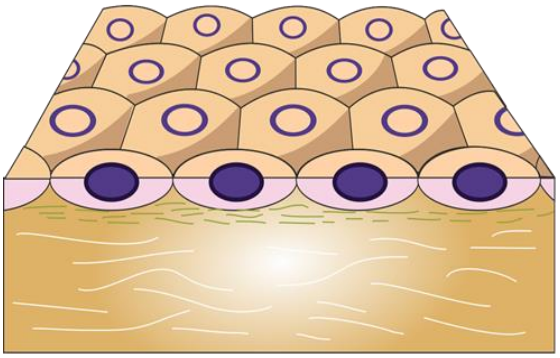
(3) Association

(4) Organisation as a structure

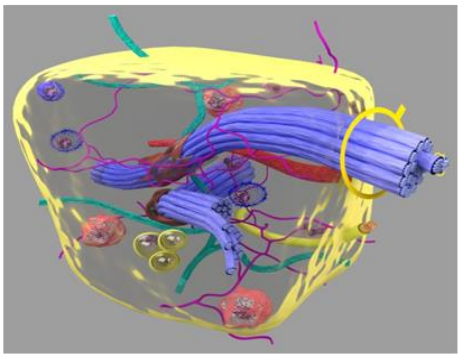
Answer: (2) Division of labour

ON THE BASIS OF FUNCTIONS AND STRUCTURE TISSUES ARE OF FOUR TYPES :

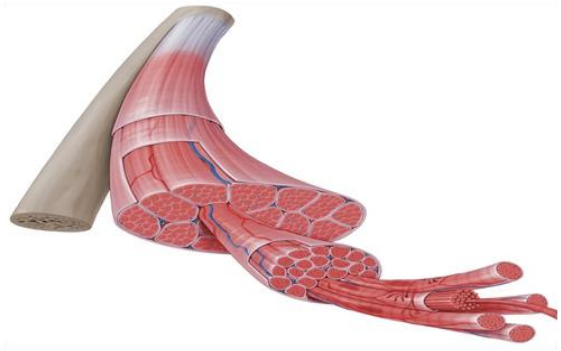
1. **Epithelium/Epithelial Tissue–** Covering & protective tissue.
2. **Connective Tissue–** To connect structures, provide support to the body and transport substances in the body.
3. **Muscular Tissue–** Helps in contraction & locomotion.
4. **Nervous tissue–** To generate and conduct nerve impulses in body.



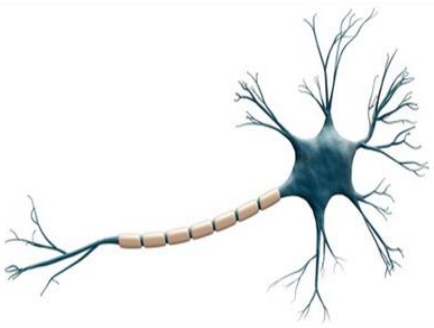
Epithelial tissue



Connective tissue



Muscular tissue



Nervous tissue

HISTORICAL BACKGROUND :

- Word epithelium was given by – **Ruysch**

- Word animal tissue was coined by – **Bichat**

- Word plant tissue was coined by – **N. Grew**

- Study of tissue is called **Histology**
- Histology word was given by **Mayer**
- Father of histology – **Bichat**
- Detail study of tissue is called **Microscopic anatomy.**
- Founder of microscopic anatomy – **Marcello Malpighi**

Question-1: Select the odd one out –

(1) Epithelial (2) Connective (3) Lymphoid (4) Neural

Answer: (3) Lymphoid

Question-2: Which of the following is a function of connective tissue?

(1) To make body mass (2) To connect various parts of body

(3) Both (4) None of the above

Answer: (2) To connect various parts of body

Question-3: Term animal tissue was coined by –

(1) Mayer (2) Frederick Ruysch (3) Alan Jones (4) Xavier Bichat

Answer: (4) Xavier Bichat

Question-4: Which of the following tissue type is responsible for generation and conduction nerve impulses in body?

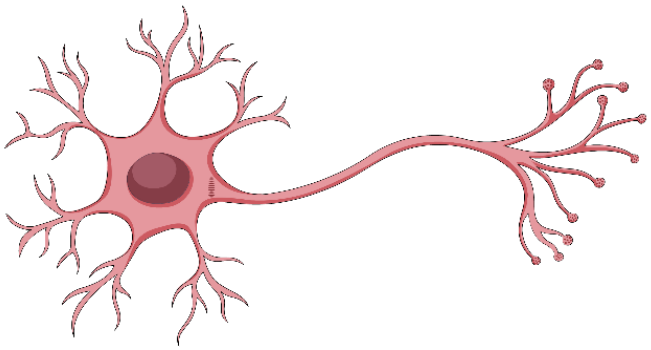
(1) Nervous tissue (2) Muscle tissue (3) Connective tissue (4) Lymphoid tissue

Answer: (1) Nervous tissue

EPITHELIAL TISSUE :

- Word epithelium is derived from two words – epi and thelia
- Epi – upon, thelia – growth
- These tissues develop first during embryonic development.

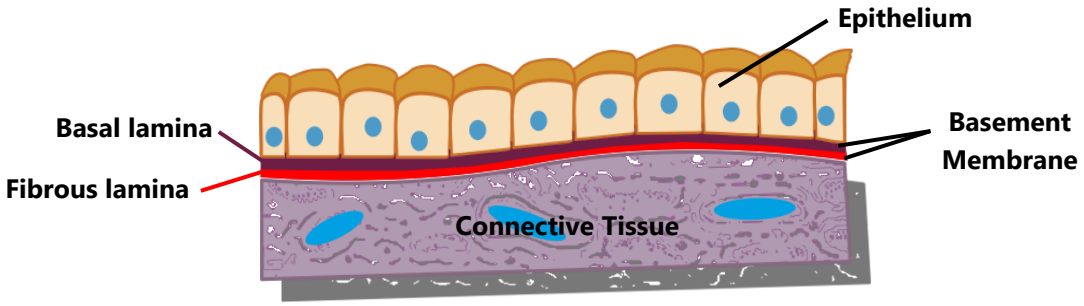
- Power of regeneration is present in this tissue while power of regeneration is absent or least power is found in nervous tissue.



- Epithelium cells are compactly packed with little intercellular matrix.
- Because of very little intercellular spaces blood capillaries and lymph capillaries are absent.
- It always rest upon underlaying connective tissue.
- Cells of epithelial tissues derive their nutrition from underlying connective tissue.
- In between epithelium and connective tissue basement membrane is present.
- **Basement membrane :** Between epithelium and connective tissue, a thin non-living acellular basement membrane is present which is highly permeable. Basement membrane consist of 2 layers.

(a) **Basal lamina :** Towards epithelium and it is made up of glycoprotein, which is secreted by epithelium cells.

(b) **Fibrous lamina :** Towards connective tissue, in which collagen and reticular fibres are suspended in mucopolysaccharide which is matrix of connective tissue. Mucopolysaccharide is present in the form of Hyaluronic acid. So basement membrane is secreted by both epithelium and connective tissue.



- This tissue has a free surface, which faces either a body fluid (examples epithelium of blood vessels, epithelium of nephron, epithelium of stomach and intestine etc.) or the outside environment (examples nails, horns, hoof, feathers, scales) and thus provides a covering or a lining for some part of the body.

Question-1: Correct statement about epithelial tissue is –

(1) Tissue has a free surface
(2) Faces either a body fluid or the outside environment
(3) Provides a covering or a lining for some part of the
(4) All of the above

Answer: (4) All of the above

Question-2: Blood capillaries and lymph capillaries are absent in epithelial tissue because –

(1) It does not require nutrition
(2) Very little intercellular spaces
(3) Derives nutrition from outside environment
(4) Statement is not true for all epithelial tissue

Answer: (2) Very little intercellular spaces

Question-3: Fibrous lamina is secreted by –

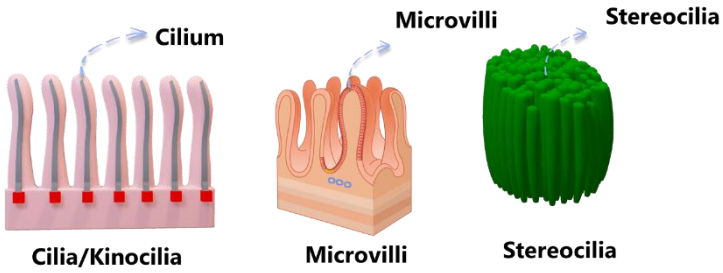
(1) By connective tissue (2) By basement membrane
(3) By dead epithelial tissue (4) By fibroblast

Answer: (1) By connective tissue

MODIFICATIONS OF PLASMA MEMBRANE AND CELL JUNCTIONS :

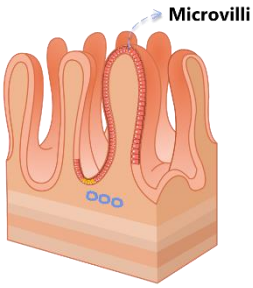
EPITHELIUM/EPITHELIAL TISSUE

Modification of Plasma Membrane



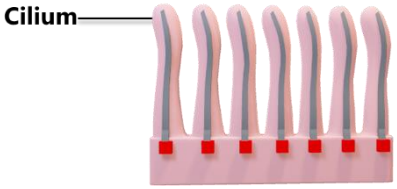
MICROVILLI

- Minute process, **Non-motile, Non-contractile.**
- **Function-** Increase surface area for **absorption & secretion.**
- **Example-** Wall of **intestine, Gall bladder, PCT of Nephron.**

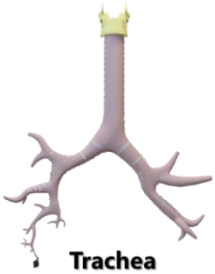


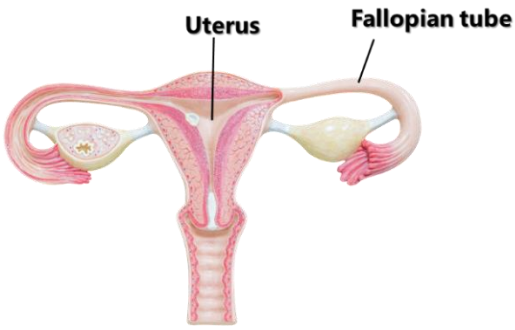
CILIA/KINOCILIA

- Long cylindrical process **(same diameter from base to apex). Motile and Contractile.**
- It moves particles or mucous in specific direction over the epithelium. (Movement is in **uniform direction**).

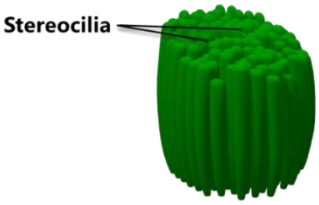


- **Function-** Helps in **movement & locomotion.**
- **Example-** Inner surface of hollow organs like **bronchioles & fallopian tube, Uterus, Trachea, Ependymal epithelium.**

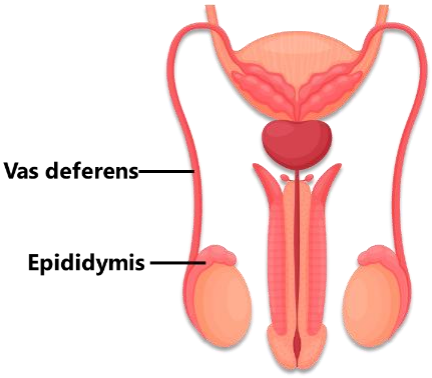




STEREOCILIA



- Conical shape, Non-motile, Non-Contractile.
- **Function-** Increase surface area.
- **Examples- Epididymis & Vas deferens.**



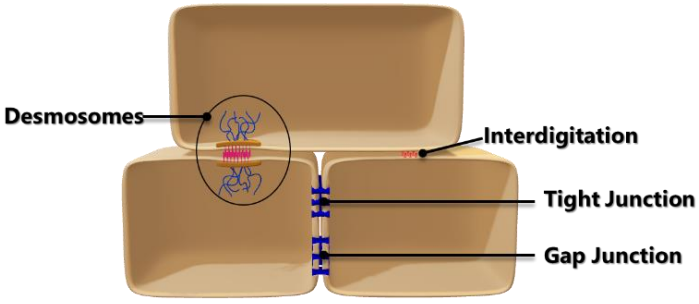
Types of Cell Junction

Four types of cell junctions

1. Interdigitations
2. Tight junctions
3. Desmosomes
4. Gap junctions

CELL JUNCTION :

- Cell junctions are found in epithelium and other tissues.
- These specialised junctions provide both **structural & functional links** between its individual cells.



1. **Interdigitations- Finger like** processes of plasma membrane which enter into cytoplasm of adjacent cell.
   Mainly found in **Stretchable/Transitional Epithelium.**
2. **Tight junctions-** Stop substances from **leaking** across a tissue.
3. **Desmosomes-**
   Perform **cementing** to keep neighbouring cells together.
   Mostly found in **Non-stretchable epithelium.**
   Provide **mechanical support** to Non-stretchable epithelium.
   Also called as **Macula Adherens**.
   Contain intermediate fibres known as **Tonofibrils**.

4. **Gap junctions-** Facilitate the cells to **communicate** with each other.
Rapid transfer of ions, small molecules and sometimes big molecules.

Microvilli	Cilia/Kinocilia	Stereocilia
Minute process	Long cylindrical process (same diameter from base to apex)	Conical shape
Non-motile	Motile	Non-motile
Non-contractile	Contractile	Non-contractile
Function- • Increase surface area for absorption & secretion	**Function-** • Helps in movement & locomotion. • It moves particles or mucous in specific direction over the epithelium. (Movement is in uniform direction)	**Function-** • Increase surface area
Example- Wall of intestine Gall bladder PCT of Nephron	**Example-** Inner surface of hollow organs like bronchioles & fallopian tube. Uterus, Trachea Ependymal epithelium	**Example-** Epididymis & Vas deferens

Question-1: Stereocilia present in –
(1) Epididymis (2) Seminal vesicle (3) Ureter (4) Kidney
Answer: (1) Epididymis

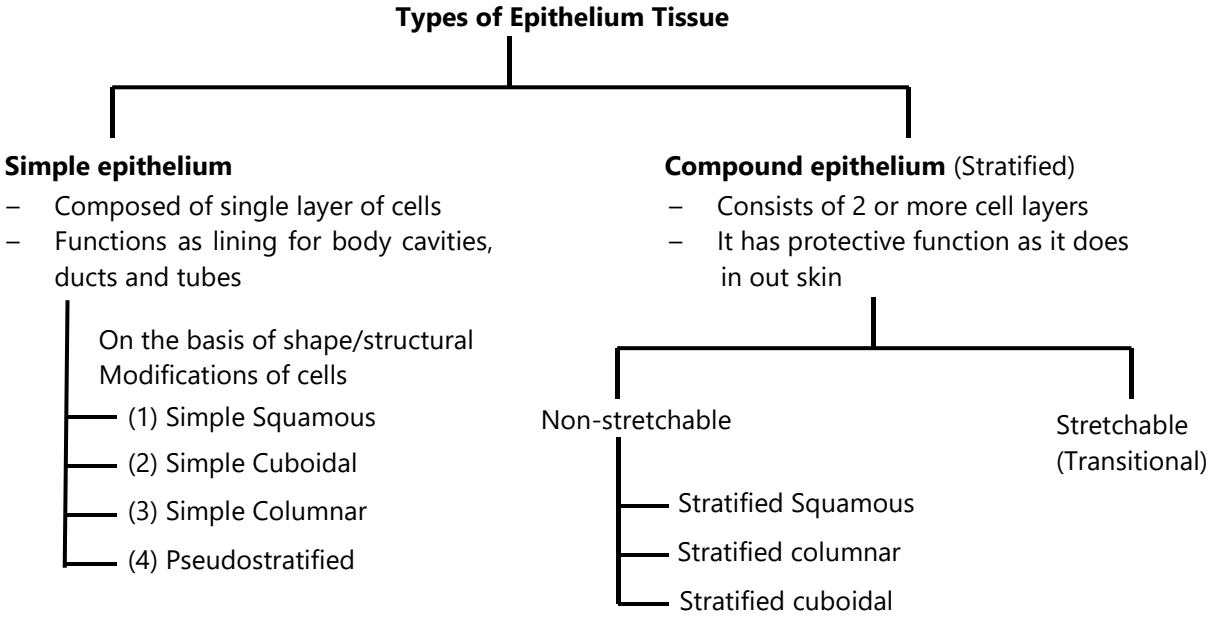
Question-2: Lining of brain ventricle & central canal of spinal cord is lined by –
(1) Ependymal epithelium (2) Endothelium
(3) Mesothelium (4) Neurosensory
Answer: (1) Ependymal epithelium

Question-3: Desmosomes –
(1) Connect the epithelial cells (2) Are types of lysosomes
(3) Are granules of muscle fibres (4) Found in bone
Answer: (1) Connect the epithelial cells

Question-4: Ciliated epithelium is found in –
(1) Oviduct (2) Trachea (3) Brain ventricles (4) All of these
Answer: (4) All of these

Question-5: Gap junctions –
(1) Help to stop substances from leaking across a tissue.
(2) Perform cementing to keep neighbouring cells together
(3) Provide stretchability to the epithelium
(4) Facilitate the cells to communicate with each other by connecting the cytoplasm of adjoining cells.
Answer: (4) Facilitate the cells to communicate with each other by connecting the cytoplasm of adjoining cells.

CLASSIFICATION OF EPITHELIAL TISSUE :


Types of Epithelium Tissue
Simple epithelium
– Composed of single layer of cells
– Functions as lining for body cavities, ducts and tubes
On the basis of shape/structural Modifications of cells
(1) Simple Squamous
(2) Simple Cuboidal
(3) Simple Columnar
(4) Pseudostratified
Compound epithelium (Stratified)
– Consists of 2 or more cell layers
– It has protective function as it does in out skin
Non-stretchable
Stretchable (Transitional)
Stratified Squamous
Stratified columnar
Stratified cuboidal

- All the cells of simple epithelium rest upon basement membrane.
- Only the cells of lowermost layer rest upon basement membrane.

Question-1: Which of the following is an ectodermal origin epithelial tissue?

(1) Epidermis (2) Mesothelium

(3) Gastro-intestinal tract (4) Dermis

Answer: (1) Epidermis

Question-2: Which of the following tissue functions as lining for body cavities, ducts, and tubes?

(1) Compound (2) Simple (3) Both (4) None of the above

Answer: (2) Simple

Question-3: Amongst the following which of these epithelium exhibits the property of stretch ability.

(1) Simple squamous (2) Stratified cuboidal

(3) Pseudostratified epithelium (4) Transitional epithelium

Answer: (4) Transitional epithelium

Question-4: Based on shape/structural modifications of cells, how many type of division of simple epithelium are there?

(1) Zero (2) One (3) Two (4) Three

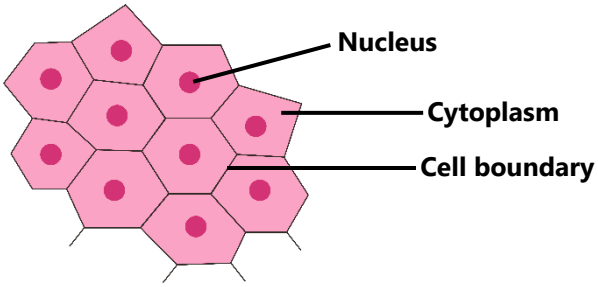
Answer: (4) Three

SIMPLE EPITHELIUM :

- Made up of single layer of cells.
- All the cells rest upon basement membrane.
- Functions as lining for body cavities, ducts and tubes.

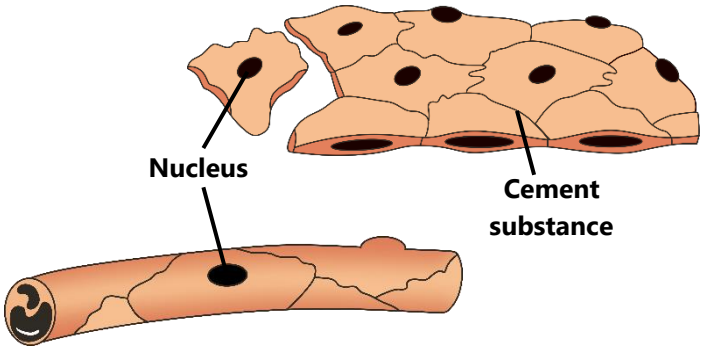
SIMPLE SQUAMOUS EPITHELIUM :

- The squamous epithelium is made of a single thin layer of flattened cells with irregular boundaries.
- They are found in the **walls of blood vessels** and **air sacs of lungs** and are involved in a function like forming a **diffusion boundary**.
- It is also called **pavement epithelium** due to its tile like appearance.

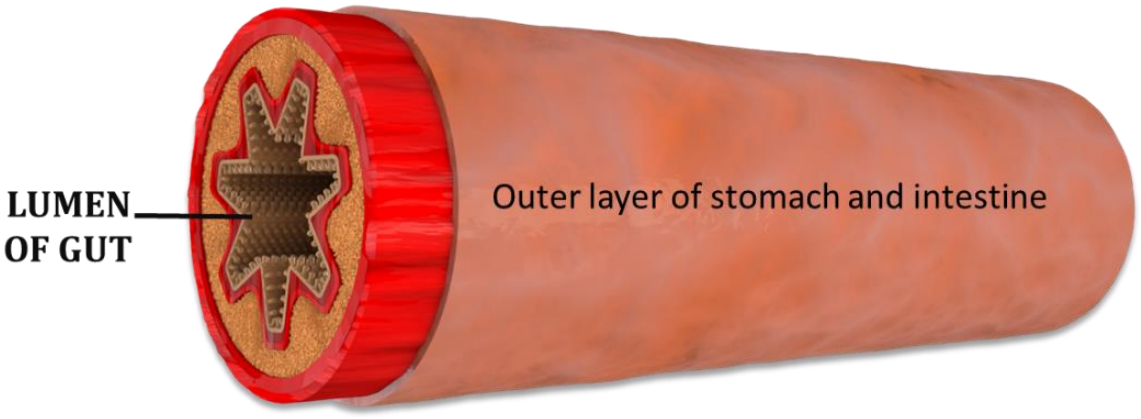


(Simple Squamous Epithelium)

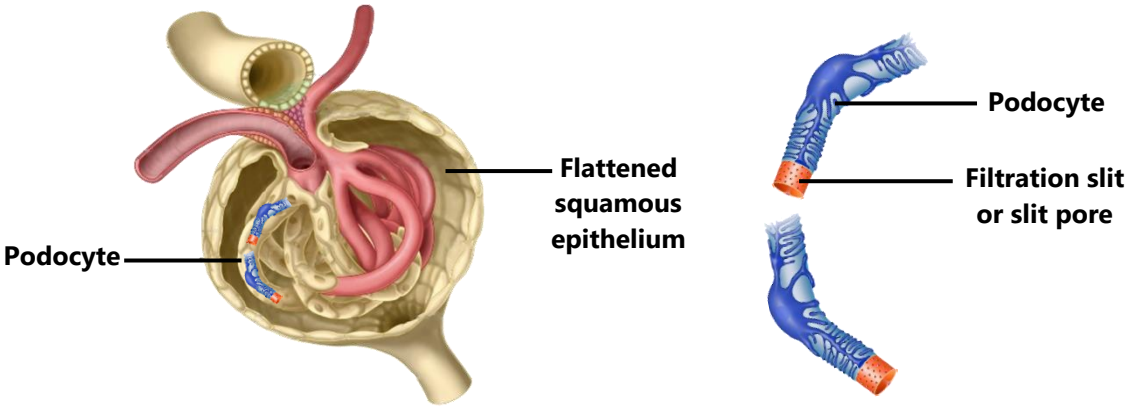
- Also called **Tesselated** epithelium due to its wavy appearance in blood vessel and coelom.



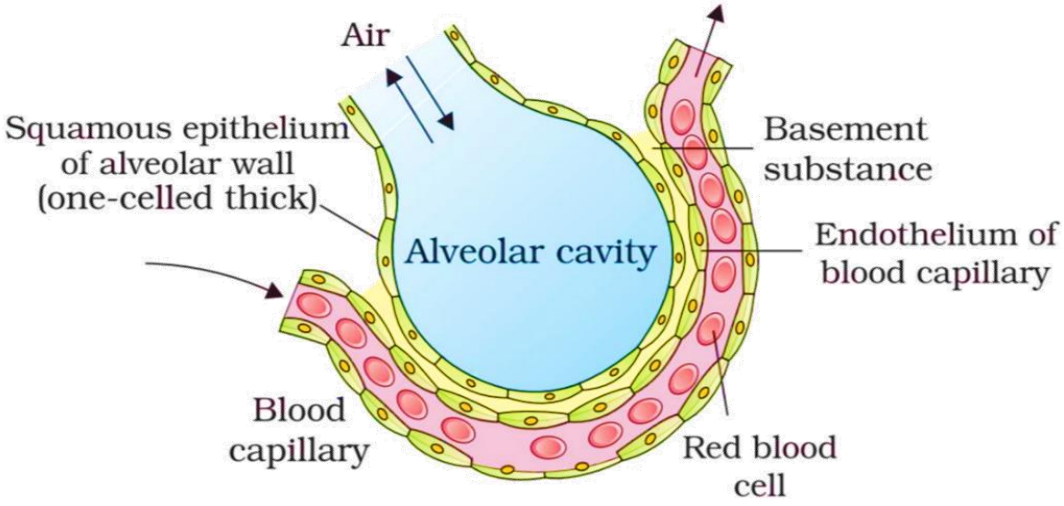
- This epithelium is associated with filtration & diffusion.
- This epithelium is found in outer surface of stomach and intestine.



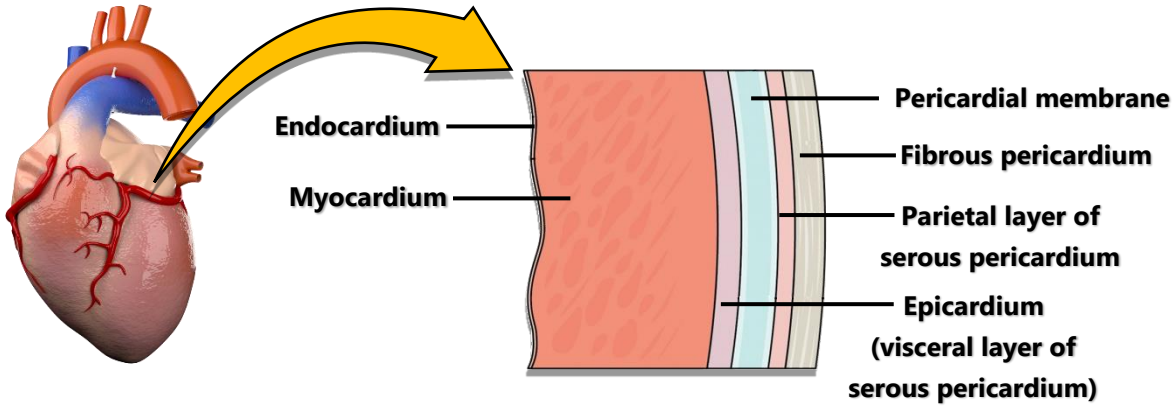
- Bowman's capsule (Podocyte)



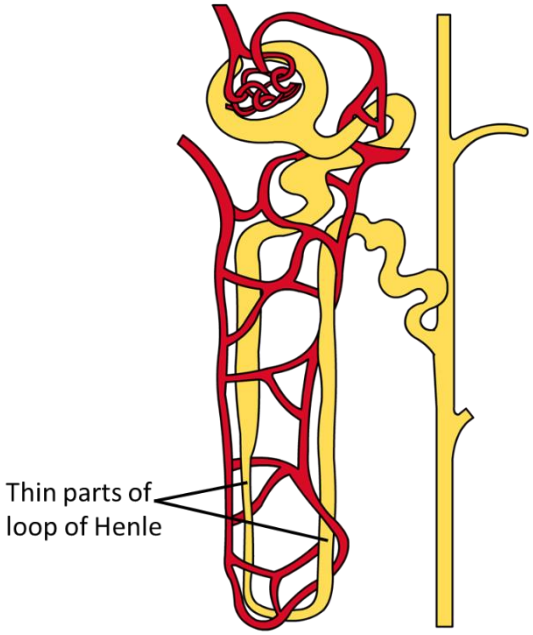
- Alveoli of lungs (Pneumocytes type-I) (air sacs of lungs)
- **Endothelium –** Inner lining of blood vessels and lymph vessels.



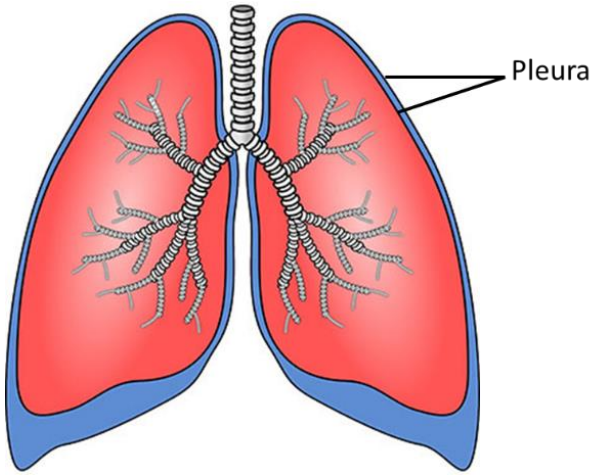
- **Mesothelium –** Covering of coelom is called as mesothelium.
- **Endocardium –** Inner most lining of heart is also made up of simple squamous epithelium.
- Parietal layer of pericardium and epicardium of heart is also made up of simple squamous epithelium.



- Thin part of loop of Henle of nephron.



- **Pleura –** Covering of lungs are lined by simple squamous epithelium.



Question-1: The internal lining of blood vessels is called as –

(1) Mesothelium
(2) Endothelium
(3) Pavement Epithelium
(4) Stratified epithelium

Answer: (1) Endothelium

Question-2: Cells of peritoneum comprise –

(1) Ciliated Epithelium
(2) Glandular Epithelium
(3) Columnar Epithelium
(4) Squamous Epithelium

Answer: (4) Squamous Epithelium

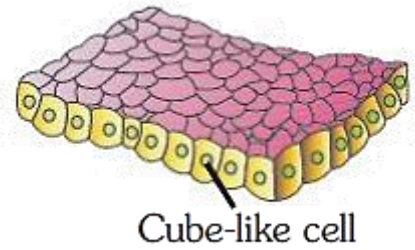
Question-3: Which of the following consists of simple squamous epithelium?

(1) Blood vessels
(2) Alveoli of lungs
(3) Outer surface of intestine
(4) All of the above

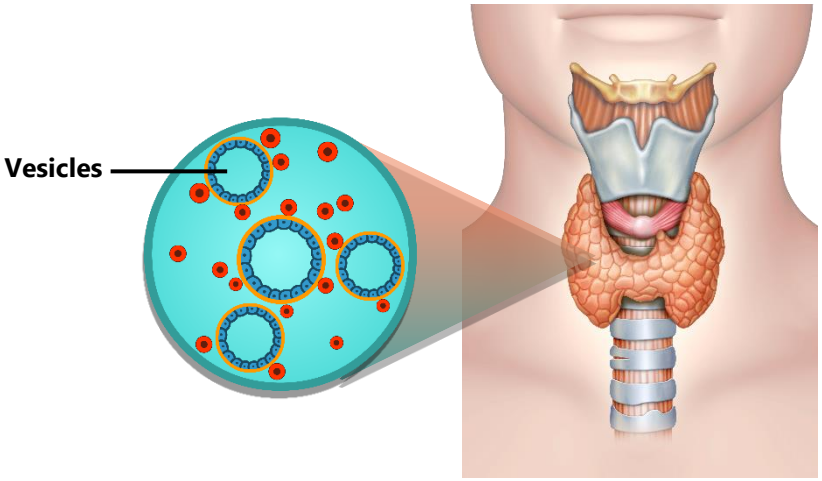
Answer: (3) All of the above

SIMPLE CUBOIDAL EPITHELIUM :

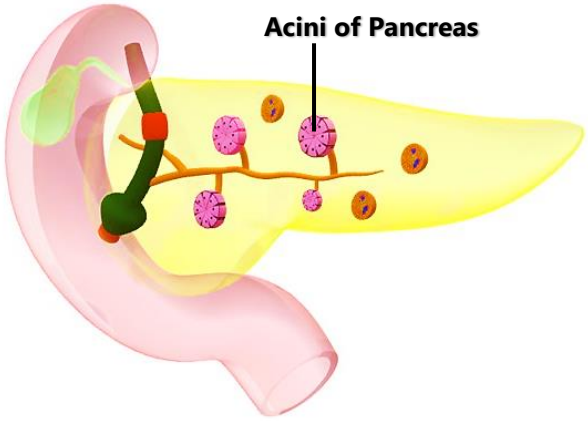
- The cuboidal epithelium is composed of a single layer of cube-like cells.
- Cells are cube like in shape.



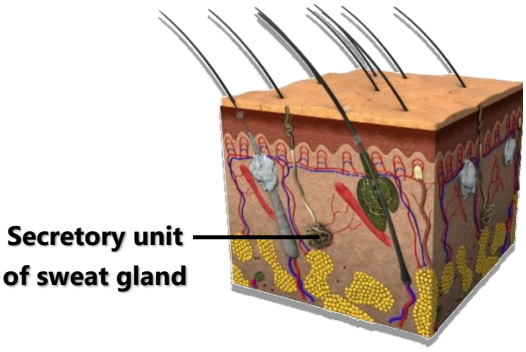
- This is commonly found in ducts of glands and tubular parts of nephrons in kidneys.
- Its main functions are secretion and absorption.
- **Vesicles of thyroid gland**



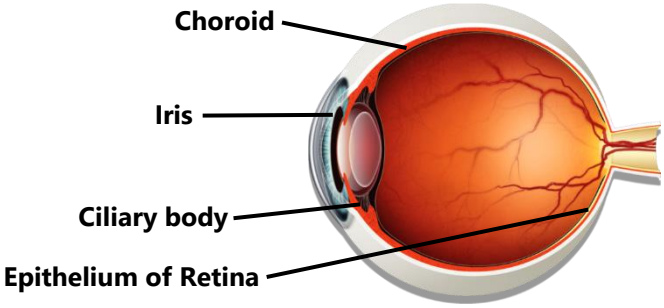
- **Acini of pancreas – synthesise and secrete pancreatic juice**



- **Sweat glands –**



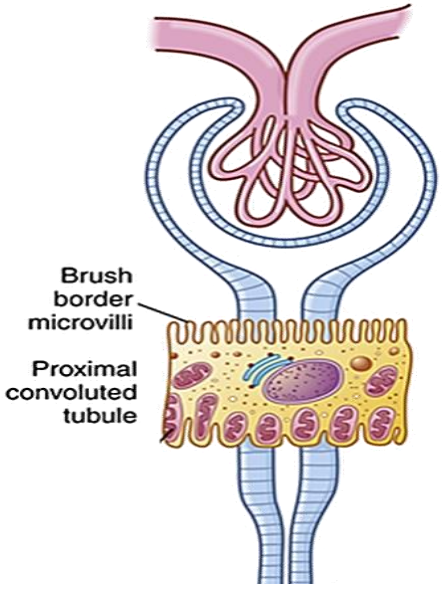
- **Eye –**



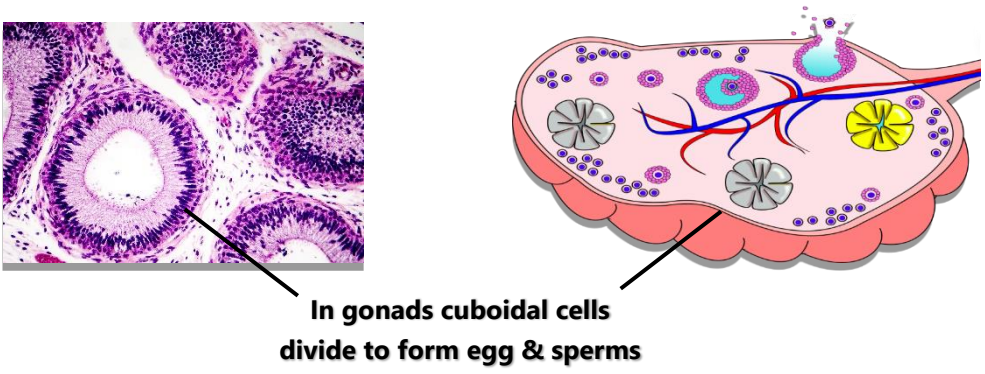
- Modifications of simple cuboidal epithelium

(i) Brush bordered cuboidal epithelium :

When microvilli are present on free end of cuboidal cells then it is called as brush bordered cuboidal epithelium. It is found in PCT of nephron.



(ii) This epithelium is also called Germinal epithelium because in gonads (testis & ovaries) cuboidal cells divide to form egg & sperm.



Question-1: Which of the following epithelium is also known as Germinal epithelium?

(1) Simple columnar epithelium
(2) Simple cuboidal epithelium
(3) Stratified columnar epithelium
(4) Transitional epithelium

Answer: (2) Simple cuboidal epithelium

Question-2: Identify the following diagram –

(1) Simple columnar epithelium
(2) Transitional epithelium
(3) Simple cuboidal epithelium
(4) Simple squamous epithelium

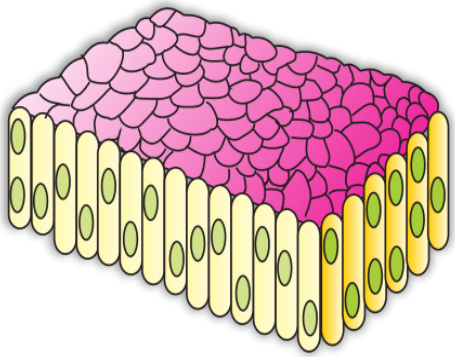
Answer: (3) Simple cuboidal epithelium

Question-3: Main function of simple cuboidal epithelium is –

(1) Diffusion
(2) Absorption only
(3) Secretion only
(4) Secretion and absorption both

Answer: (4) Secretion and absorption both

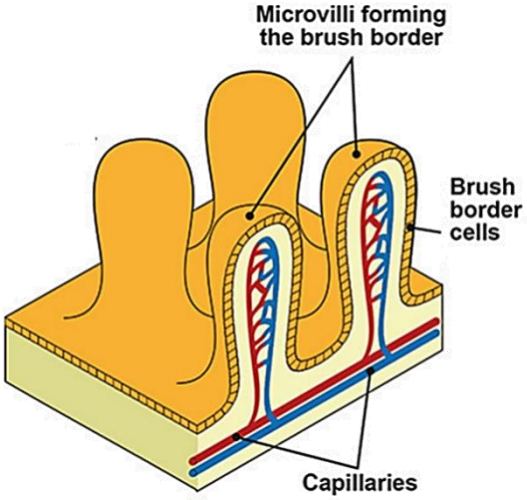
SIMPLE COLUMNAR EPITHELIUM :

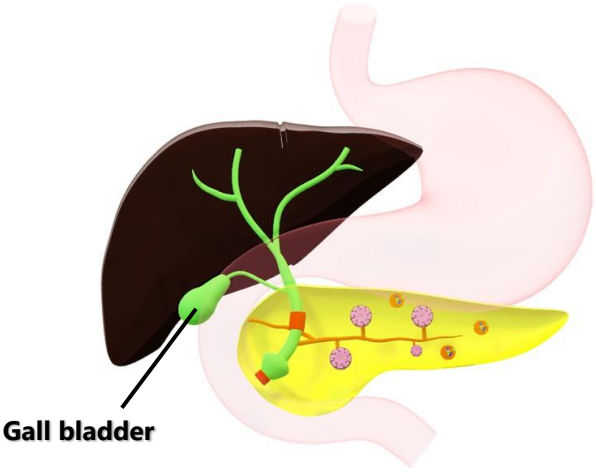


- The columnar epithelium is composed of a single layer of cylindrical cells.
- Nucleus is present at the base of the cell and is elongated.
- Cells are more in length and less in width so, they appear pillar shaped in vertical section.
- **Function** : It helps in absorption and secretion.

MODIFICATIONS OF SIMPLE COLUMNAR EPITHELIUM :-

(a) **Brush Bordered Columnar epithelium :** When microvilli are present on free end of columnar epithelium. **e.g.** Gall bladder

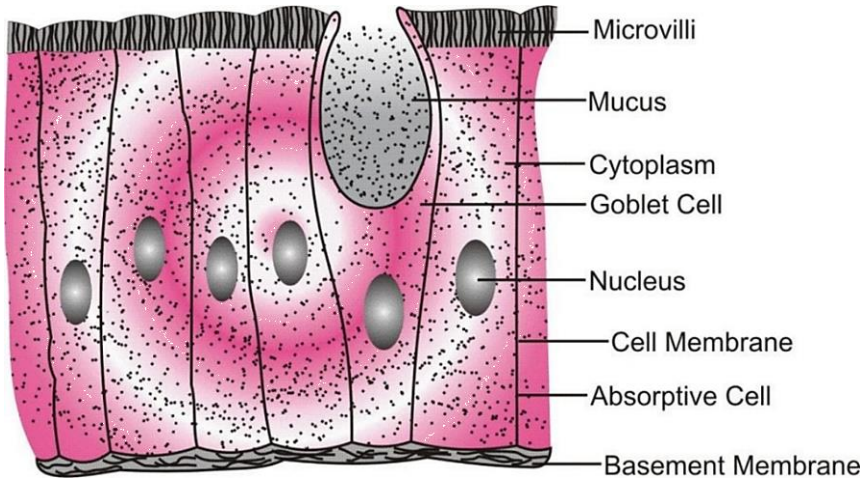


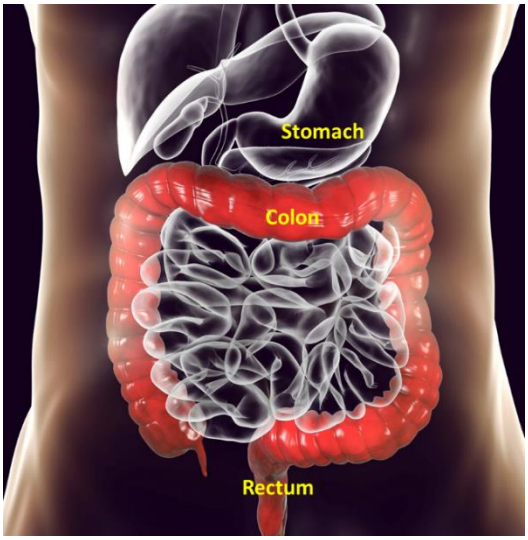


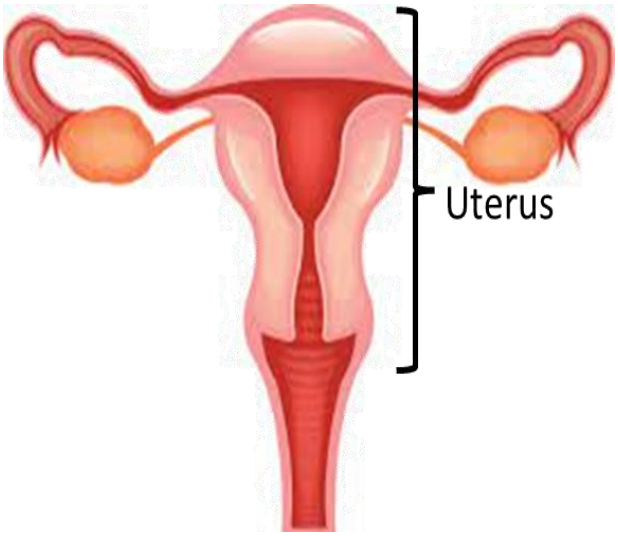
(b) **Glandular columnar epithelium :**

Unicellular mucous secreting goblet cells are also present in between columnar cells.

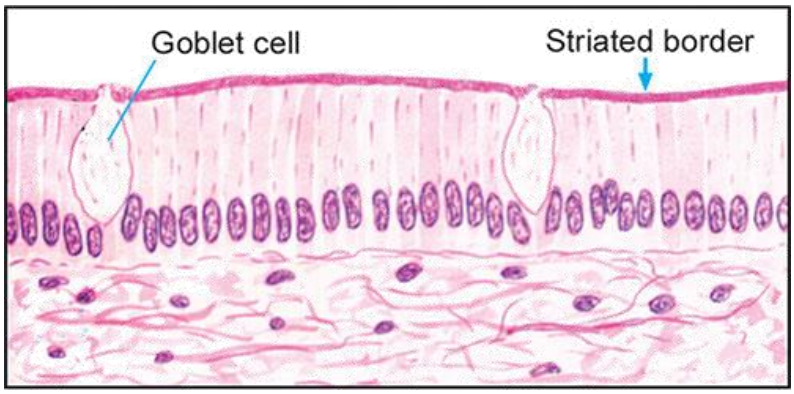
e.g. Stomach, Colon, Rectum and Uterus

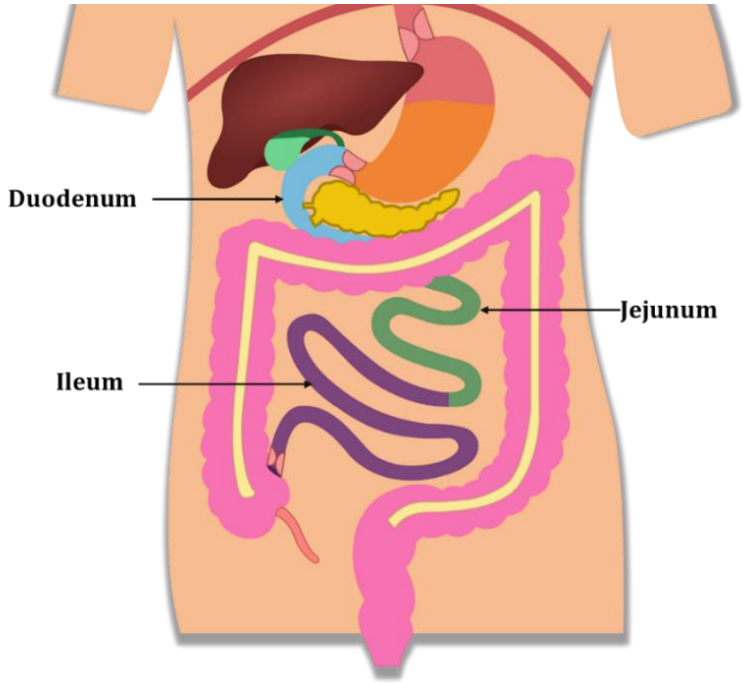




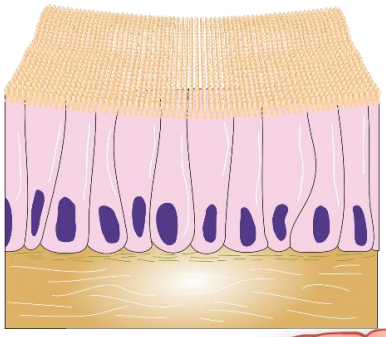


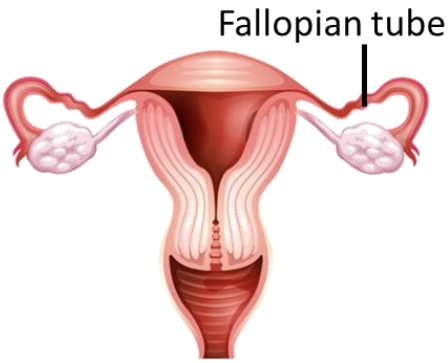
(c) **Glandular brush bordered columnar epithelium :** When microvilli present on free end of columnar cells and in between these cells goblet cells are also present. **e.g.** Duodenum, jejunum and Ileum

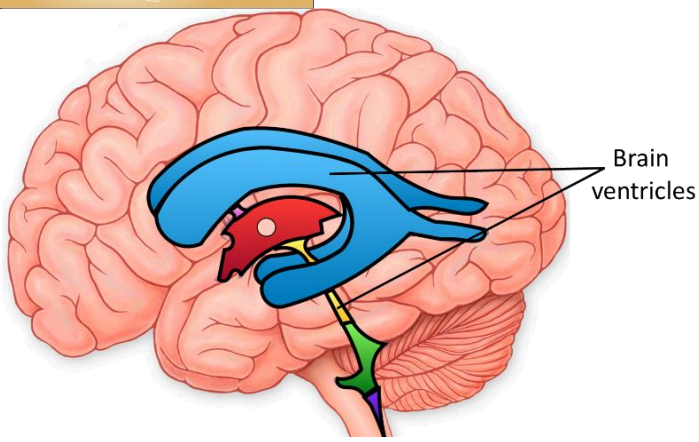




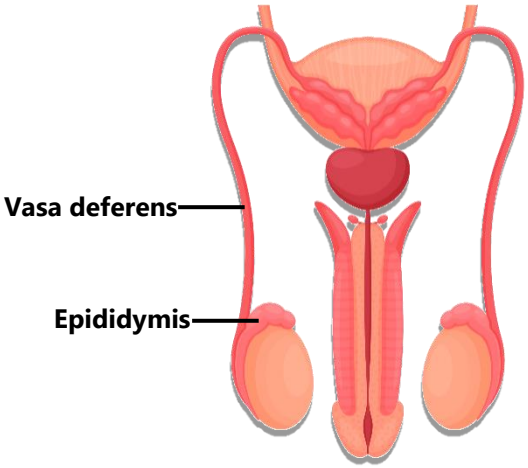
(d) **Simple columnar ciliated epithelium :** When cilia are present on free end of columnar cells.
e.g. Fallopian tube and Ependymal epithelium of brain ventricles.







(e) **Simple columnar stereociliated epithelium :** When stereocilia are present on free end of columnar cells. **e.g.** vasa deferens, epididymis, internal ear

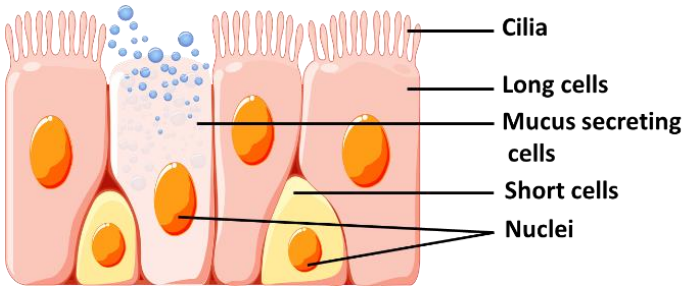


PSEUDOSTRATIFIED EPITHELIUM :

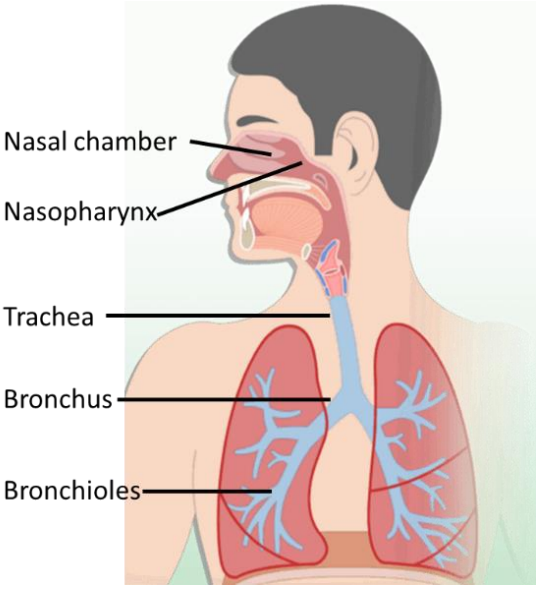
- These cells are pillar like in shape so it is also a modification of columnar epithelium.
- In this epithelium two types of cells are present i.e. Long cells, Short cells.
- Nucleus in both cells are present on different level so it appears bilayered because few cells are too short to reach the top surface.
- But all cells are present on single basement membrane so it is unlayered.

PSEUDOSTRATIFIED EPITHELIUM COLUMNAR CILIATED GLANDULAR EPITHELIUM :

- In this epithelium cilia are present of free end of long cells and mucus secreting cells are also present in this epithelium.



e.g. nasopharynx, Trachea, Bronchus, Bronchioles, Respiratory epithelium of nasal chambers.

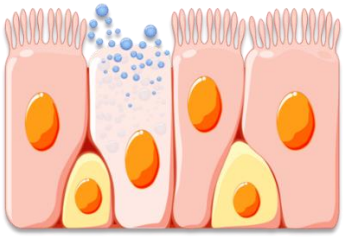


Question-1: Gall bladder performs the function of –

(1) Dilution of bile juice
(2) Concentration of bile juice only
(3) Only storage of bile juice
(4) Concentration and storage of bile juice

Answer: (2) Concentration and storage of bile juice

Question-2: Identify the following diagram –



(1) Simple squamous
(2) Stratified cuboidal
(3) Pseudostratified epithelium
(4) Transitional epithelium

Answer: (3) Pseudostratified epithelium

Question-3: Main function of simple brush border glandular columnar epithelium is –

(1) Absorption (2) Digestion (3) Secretion (4) Protection

Answer: (3) Absorption

Question-4: Pseudostratified epithelium is the modification of –

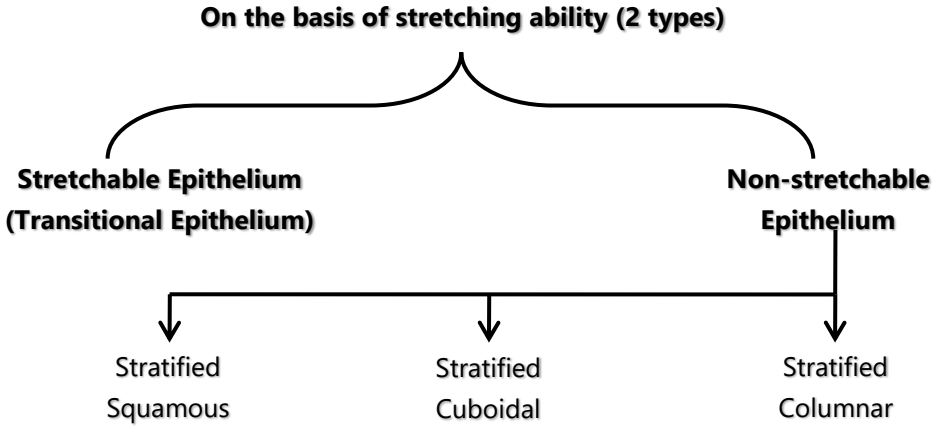
(1) Transitional epithelium (2) Cuboidal epithelium

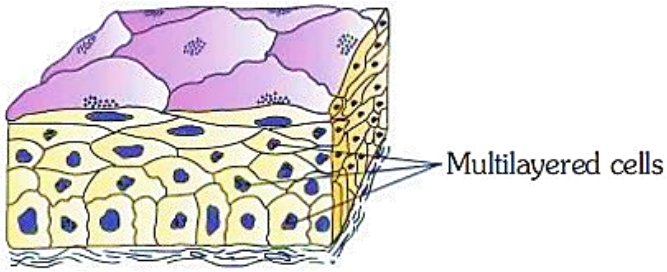
(3) Columnar epithelium (4) Squamous epithelium

Answer: (3) Columnar epithelium

COMPOUND EPITHELIUM :

- It is multi-layered and have limited role in secretion and absorption.
- It provides protection against chemical & mechanical stress.

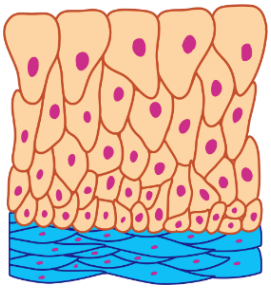


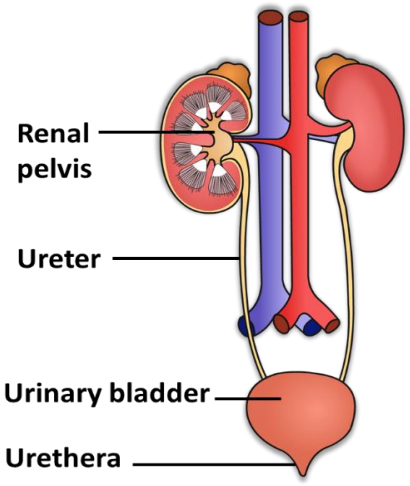


TRANSITIONAL EPITHELIUM (UROTHELIUM) :

- In this epithelium basement membrane becomes invisible during stretching.
- In this epithelium 4-6 layers of cells are present.
  – Inner most layer of cell is composed of cube like cells.
  – Middle 2-4 layers are composed of pear shaped /Polyhedral cells.
  – Outermost 1 or 2 layers are of oval shaped cells.
- This different shape of cells appears only in resting stage. When this tissue is stretched, all the cells become flattened.
- Cells are interconnected by interdigitation.
- Stretchable & waterproof.

- **e.g. –** Renal pelvis, Ureter, Urinary bladder, Proximal part of male urethra.





NONSTRETCHABLE EPITHELIUM :

On the basis of shape of the cells of outermost layer it is of three types.

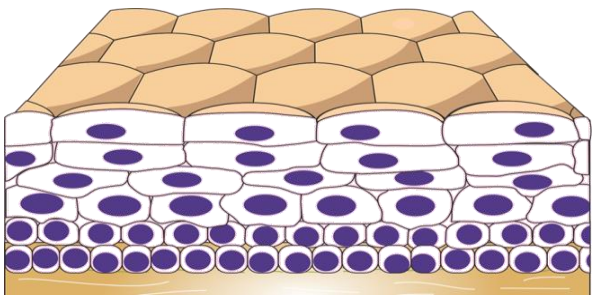
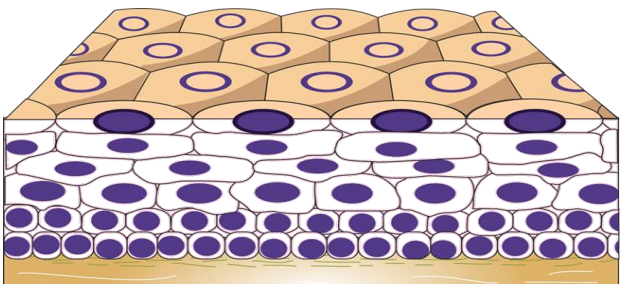
(1) Stratified squamous epithelium

(2) Stratified cuboidal epithelium

(3) Stratified columnar epithelium

STRATIFIED SQUAMOUS EPITHELIUM :

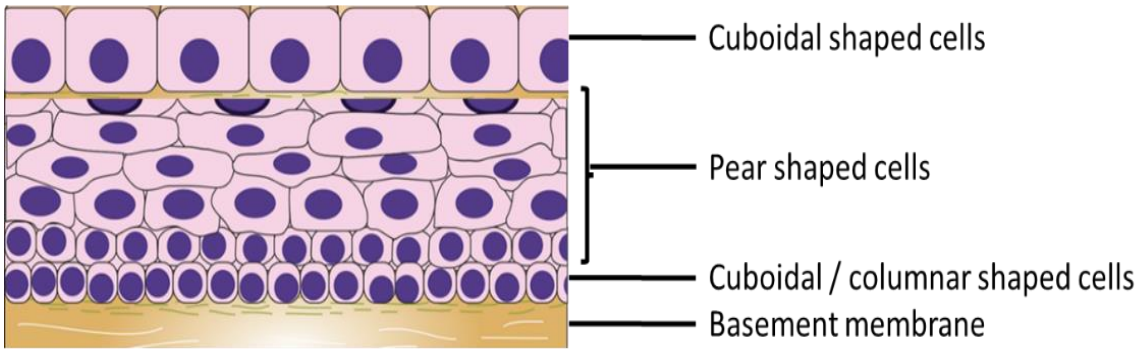
- Innermost layer of cells is of cuboidal or columnar shaped.
- They divide to form cells of outer layer in the epithelium, so this layer is called as Germinativum layer.
- Middle layers are made up of polygonal cells.
- These cells are interconnected with desmosomes which provide rigidity or mechanical support.
- Cells of outermost layer are scale like flat cells.
- On the basis of presence of keratin protein in the outer most cells this epithelium is of two types.

Keratinized stratified squamous epithelium	Non-Keratinized stratified squamous epithelium
If keratin protein is present, cells become non nucleated and dead.	If Keratin protein is absent. Cells are nucleated and living.
	

STRATIFIED CUBOIDAL EPITHELIUM :

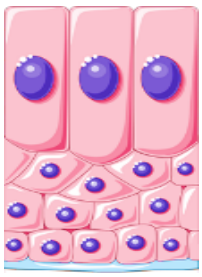
- In this epithelium 4-6 layers of cells are present. – Inner most layer of cell is composed of cube like cells.

- Middle 2-4 layers are composed of pear shaped /Polyhedral cells.
- Cell of outermost layer are cube like, nucleated and living.



STRATIFIED COLUMNAR EPITHELIUM :

- In this epithelium 4-6 layers of cells are present. – Inner most layer of cell is composed of cube like cells.
- Middle 2-4 layers are composed of pear shaped /Polyhedral cells.
- Cell of outermost layer are columnar, nucleated and living.

Stratified columnar ciliated epithelium	Stratified columnar non ciliated epithelium
Cilia are present on columnar cells	Cilia are not present
	

Compound epithelium is made of more than one layer (multi-layered) of cells and thus has a limited role in secretion and absorption. Their main function is to provide protection against chemical and mechanical stresses.
They cover the **dry surface of the skin (stratified squamous keratinised epithelium)**, the **moist surface of buccal cavity (stratified squamous nonkeratinized epithelium)**, **pharynx (stratified squamous non-keratinised epithelium)**, **inner lining of ducts of salivary glands (stratified cuboidal epithelium)** and of **pancreatic ducts (stratified cuboidal epithelium)**.

Question-1: The main function of protection against chemical and mechanical stress is provided by which type of epithelium?

(1) Simple Squamous epithelium (2) Brush border epithelium

(3) Columnar epithelium (4) Compound epithelium

Answer: (4) Compound epithelium

Question-2: Compound epithelium mainly provides covering for –

(1) Dry surface of the skin

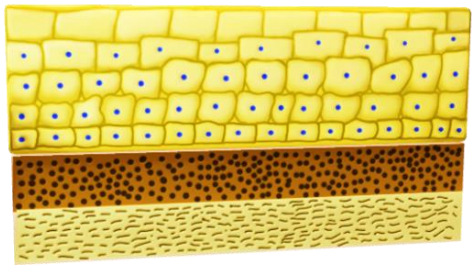
(2) The moist surface of buccal cavity

(3) Inner lining of ducts of salivary glands and of pancreatic ducts

(4) All the above

Answer: (4) All the above

Question-3: Identify the epithelium type in the following diagram –



(1) Squamous epithelium (2) Compound epithelium

(3) Ciliated columnar epithelium (4) Squamous epithelium

Answer: (2) Compound epithelium

Question-4: All the cells in non-stretchable epithelium are interconnected by –

(1) Desmosomes (2) Gap junction (3) Interdigitation (4) Hemidesmosomes

Answer: (1) Desmosomes

GLANDS :-

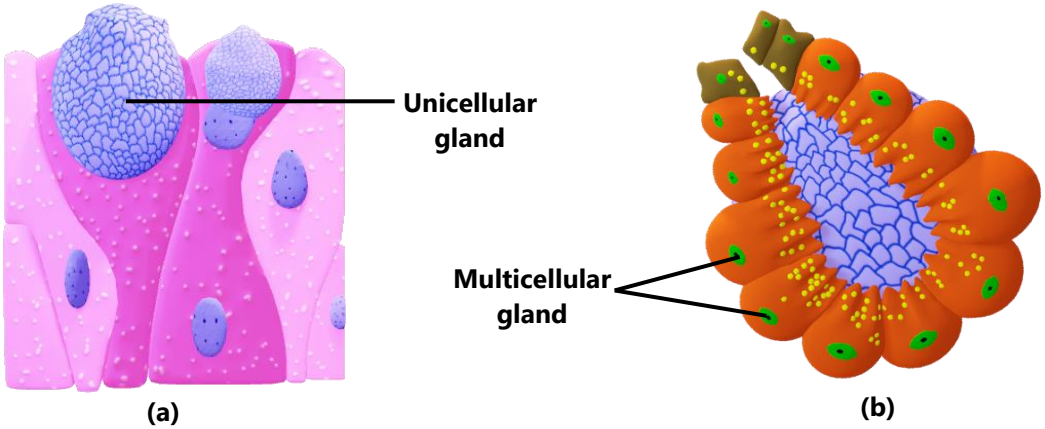
- A cell or a group of cells which secretes chemical substances are called glands.
- All glands are composed of epithelial tissue.
- Glands can be originate from all the three germinal layers.
- Ectoderm – Sweat gland
- Mesoderm – Gonads
- Endoderm – Thyroid gland

On the basis of number of cells

(a) **Unicellular glands**
e.g. Goblet cells, Paneth cells

(b) Multicellular glands
e.g. All glands except Goblet cells, Paneth cells

Some of the columnar or cuboidal cells get specialised for secretion and are called glandular epithelium (Figure). They are mainly of two types: unicellular, consisting of isolated glandular cells (goblet cells of the alimentary canal), and multicellular, consisting of cluster of cells (salivary gland).



On the basis of nature of secretion :- 3 types of glands are.
On the basis of presence of secretory duct glands are of 3 types

(a) **Endocrine glands :-** Secretory duct absent.
e.g. Thyroid, pituitary, thymus, pineal, parathyroid, adrenal

(b) **Exocrine gland :-** Secretory duct present – Liver (largest gland), Salivary gland, Gastric glands, intestinal glands etc. Exocrine glands secrete mucus (Goblet cells), saliva (Salivary glands), earwax (Ceruminous glands), oil (Sebaceous glands), milk (Mammary glands), digestive enzymes (Gastric glands, Intestinal glands) and other cell products.

(c) **Heterocrine/mixed gland :-** Both endocrine & exocrine parts are present.
e.g. Pancreas, Gonads etc.

Question-1: Which of the following is ectodermal in origin?

(1) Sweat gland (2) Thyroid gland (3) Gonads (4) Sebaceous gland

Answer: (1) Sweat gland

Question-2: Which of the following is an example of exocrine gland?

(1) Thymus gland (2) Adrenal gland (3) Salivary gland (4) Pituitary gland

Answer: (3) Salivary gland

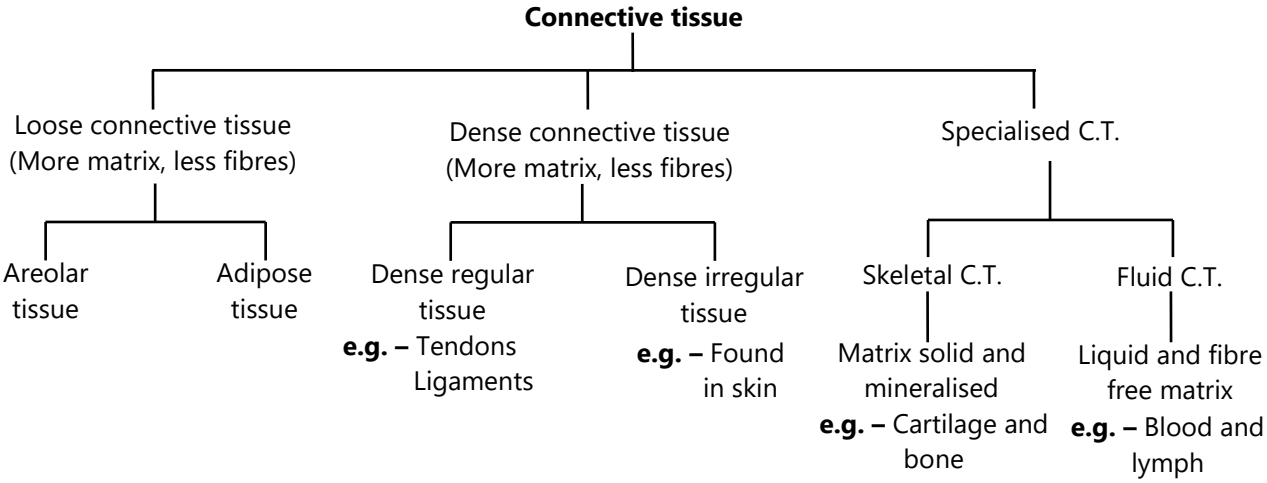
Question-3: Which of the following pair of gland is an example of unicellular gland?

(1) Salivary gland and thymus (2) Salivary gland and thyroid gland
(3) Paneth cells and Goblet cells (4) Paneth cells and sebaceous gland

Answer: (3) Paneth cells and Goblet cells

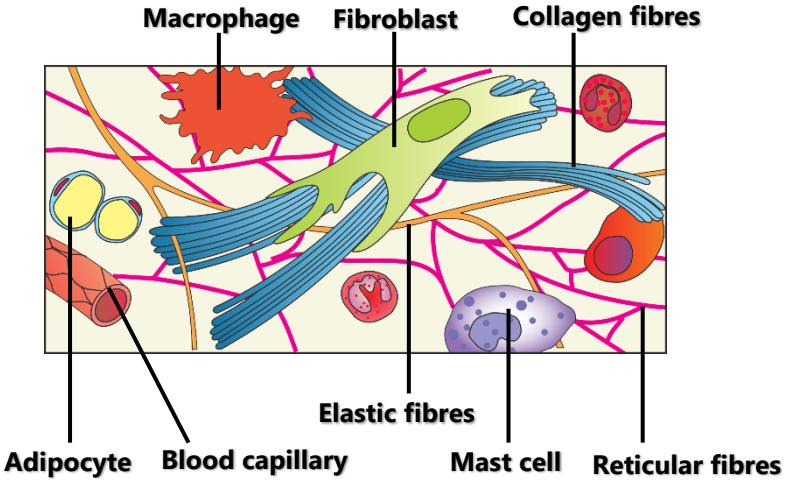
CONNECTIVE TISSUE :

- Connective tissues are the most abundant and widely distributed in the body of complex animals.
- They are named connective tissue because of their special function of linking and supporting other tissues/organs of the body fibres.
- They range from soft connective tissues to specialised types, which include cartilage, bone, adipose, and blood.
- In all connective tissues **except blood,** the cells secrete fibres of structural proteins called collagen or elastin or reticulin.
- The fibres provide strength (collagen fibres), elasticity (elastin fibres) and flexibility to the tissue.
- Connective tissue is mesodermal in origin
- These cells also secrete modified polysaccharide or mucopolysaccharides like hyaluronic acid, which accumulate between cells and fibres and acts as matrix (ground substance).



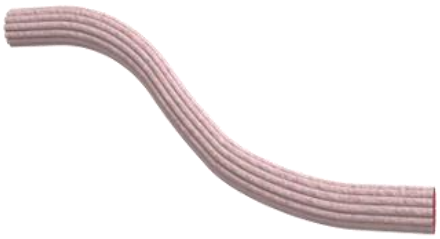
The functions of connective tissues are :

1. To connect structures.
2. To form packing around organs.
3. To form a supporting framework.
4. To combat foreign toxins.
5. To replace tissues which have been destroyed by injury.



CONNECTIVE TISSUE AND FIBRE :

(1) Collagen fibres

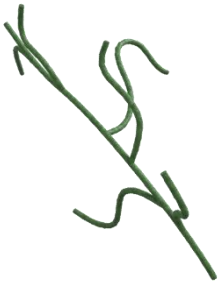


- Bright & white fibres composed of collagen protein
- Present in maximum quantity in vertebrates
- Wavy & tough fibres always arranged in bundle
- Bundle is called fascia
- Only collagen fibres constitutes one third part of connective tissue fibres

(2) Elastic fibres (Yellow fibres)

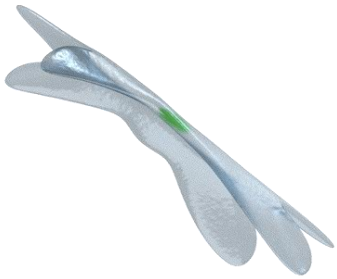
- Yellow in colour and composed of elastin protein
- Branched fibres but always arranged singly
- In these fibres maximum elasticity is present

(3) Reticular fibres



- Also known as arzyrophil fibre since they can be stained with silver salts
- Composed of reticulin protein
- Highly branched fibres which always form dense network
- Delicate fibres
- Elasticity is completely absent
- Mainly distributed in lymphoid organs like spleen or lymph nodes

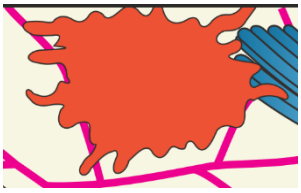
(4) Fibroblast



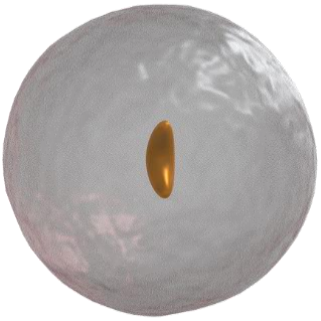
- Largest cell of connective tissue proper
- Maximum in number
- Branched cytoplasmic process arise from these cells so they appear irregular in shape
- Main function or primary function of these cells is to produces fibres. Fibres are composed of protein
- Chief matrix producing cell

(5) Macrophage

- Modified monocyte (irregular shaped)

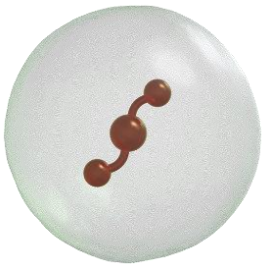


- They are phagocytic in nature. They destroy bacteria & viruses by phagocytosis



- Also called as scavenger cells of connective tissue because they destroy dead or damaged cells to clean connective tissue

(6) Mast cell



- These are like basophils of blood in structure and function
- In their cytoplasm basophilic granules are present which can be stained with basic dye methylene blue

7. Adipocytes

(i) Monolocular Adipocyte

Single large fat globule is present

(ii) Multilocular Adipocyte

Many fat globules are present

Lymphocyte

- Centrally located large nucleus
- Cytoplasm is peripheral
- Key cells of immune system
- Involved in production of antibodies

Plasma cells

- In these cells rounded nucleus is present in which chromatin material is arranged like spokes (radial rows) in wheel so they are also called as cart wheel cells
- Also called clones of lymphocytes as these are formed by division of lymphocytes
- Secrete antibodies

Question-1: Find the pair of loose connective tissue –

(1) Areolar, adipose
(2) Areolar, white fibrous
(3) White fibrous, Yellow fibrous
(4) Yellow fibrous, Adipose

Answer: (1) Areolar, adipose

Question-2: Which of the following is not an example specialised connective tissue?

(1) Blood
(2) Bone
(3) Areolar connective tissue
(4) Cartilage

Answer: (3) Areolar connective tissue

Question-3: In all connective tissues except _____, the cells secrete fibres of structural proteins called collagen or elastin or reticulin.

(1) blood
(2) bone
(3) areolar connective tissue
(4) cartilage

Answer: (1) blood

Question-4: Identify the fibres –

A - Made up of most abundant protein
B - Wavy, inelastic, tough fibres arranged in the form of bundles (fascia)
C - On boiling they yield gelatin

(1) Elastic fibres
(2) Reticular fibres
(3) Collagen fibres
(4) All of the above

Answer: (3) Collagen fibres

Question-5: Identify A, B, C and D in the given diagram :-

	A	B	C	D
(1)	Macrophage	Fibroblast	Collagen fibres	Mast cell
(2)	Macrophage	Fibroblast	Elastic fibres	Mast cell
(3)	Macrophage	Fibroblast	Reticular fibres	Mast cell
(4)	Plasma cells	Fibroblast	Collagen fibres	Mast cell

Answer: (1) Macrophage, Fibroblast, Collagen fibres, Mast cell

DENSE / FIBROUS CONNECTIVE TISSUE :

- It contains more fibres and less matrix.
- Fibres and fibroblast cells are compactly packed in dense connective tissue.
- Orientation of fibres show a regular or irregular pattern and are called dense regular and dense irregular tissue.

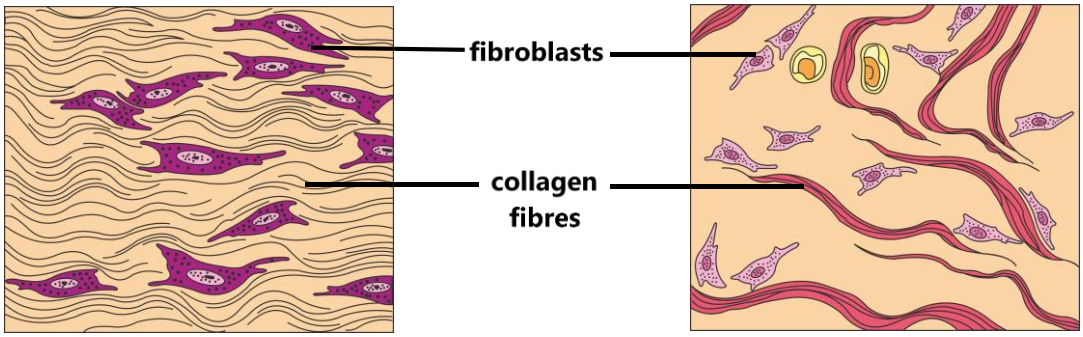
Dense connective tissue
(More matrix, less fibres)

- **Dense regular tissue**
  e.g. – Tendons and ligaments
- **Dense irregular tissue**
  e.g. – Found in skin

(A) WHITE FIBROUS CONNECTIVE TISSUE :

In this tissue bundle of collagen fibres are more in quantity whereas Yellow fibres & reticular fibres are completely absent.

- Fibroblast and mast cells are more in number.



(a) Dense regular connective tissue **(b) Dense irregular connective tissue**

On the basis of arrangement of fibres & matrix this tissue occurs in two forms.

Dense connective tissue
(Less matrix, more fibres)

Dense regular tissue (Cord)

Regular pattern of fibroblast cells and collagen fibres

White fibrous

Yellow fibrous

More yellow fibres but collagen fibres are less in quantity.

Reticular fibres - absent.

Dense irregular tissue (Sheath)

Fibroblast cells and collagen fibres are arranged in a criss–cross pattern.

White fibrous

Yellow fibrous

Bundle of collagen fibres are more in quantity

Yellow fibres & reticular fibres are completely absent.

Fibroblast and mast cells are **more** in number.

White Fibrous Connective Tissue

Irregular

- Pericardium (Covering of heart)
- Periosteum (outer covering of bone)
- Perichondrium (outer covering of cartilage)
- Epimysium (covering of muscle)
- Renal capsule (around kidney)
- Glisson's capsule (Around liver lobules)
- Duramater (outermost covering of brain)
- Cornea of eye

Regular

e.g. Tendon :- A structure which connects muscles & bones.

Yellow Fibrous Connective Tissue

Irregular

e.g. – Wall of alveoli of lungs
– Wall of small bronchioles
– Wall of lymph vessels & blood vessels
– True vocal cords

Regular

e.g. Ligaments :- (A structure which connect bones)

(C) RETICULAR FIBROUS CONNECTIVE TISSU :

- It is also called lymphoid tissue.
- It is mostly found in lymphoid organs.
- Matrix of this tissue is like lymph.
- Reticular fibres are more in amount & form dense network around reticular cells.
- Lymphocytes are also more in number.
- Provide support and strength and form the stroma (Frame work) of soft organs.
  e.g. – Spleen
  – Lymph nodes (Tonsils, Payer's Patches).

Question-1: Muscles are connected to Bone by means of –

(1) Cartilage (2) Ligaments (3) Tendon (4) Adipose tissue

Answer: (3) Tendon

Question-2: Collagen fibre and fibroblast arrangement is irregular in –

(1) Tendon (2) Ligament (3) Dura mater (4) Both (1) and (2)

Answer: (3) Dura mater

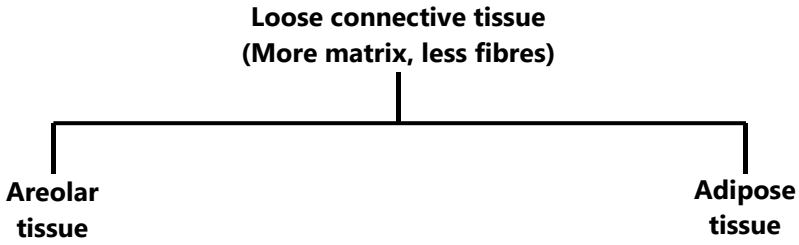
Question-3: Ligament is an example of –

(1) White fibrous dense regular connective tissue
(2) Yellow fibrous dense regular connective tissue
(3) Yellow fibrous dense irregular connective tissue
(4) White fibrous dense irregular connective tissue

Answer: (2) Yellow fibrous dense regular connective tissue

LOOSE CONNECTIVE TISSUE :

- It has more matrix and less fibres.
- The cells and fibres are loosely arranged in a semifluid ground substance.
- It is of two types :- Areolar and adipose connective tissue.



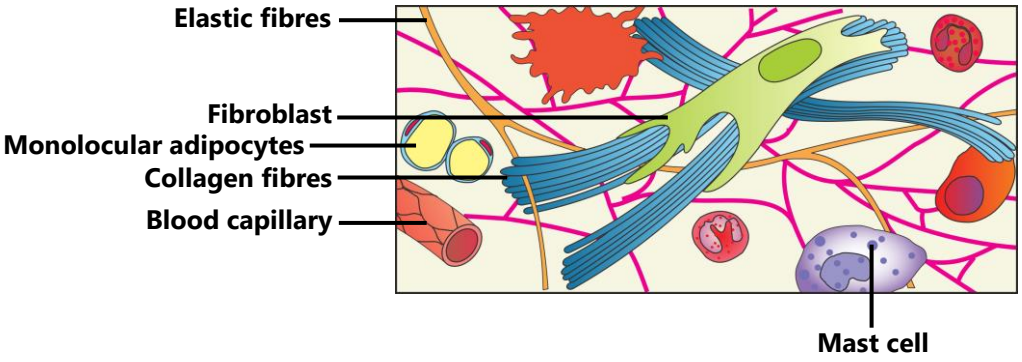
(A) AREOLAR CONNECTIVE TISSUE :

- Also known as **spongy** connective tissue.
- It is most widely distributed tissue in the body.
- In this tissue maximum intercellular space and matrix is present.
- Due to irregular arrangement of bundle of collagen fibres many gaps are present. These gaps are called **Areolae**.
- In areolae other components of connective tissue like fibres, cells & matrix are distributed.
- Few elastic fibres are present.
- It contains fibroblasts (cells that produce and secrete fibres), macrophages and mast cells.
- Mast cells, macrophages & fibroblasts are more in number.

Function :- It serves as a support framework for epithelium.

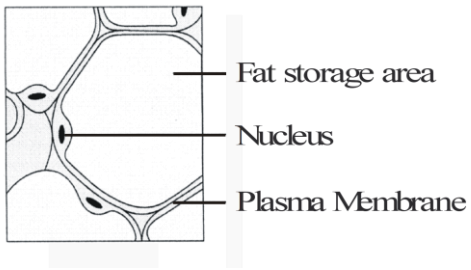
e.g. :- Tela Subcutanea :- A thin continuous layer which connect skin with underlying skeletal muscles (Panniculas carnosus) .

Sub mucosa of Trachea, Bronchi, Intestine, Oesophagus, Stomach.



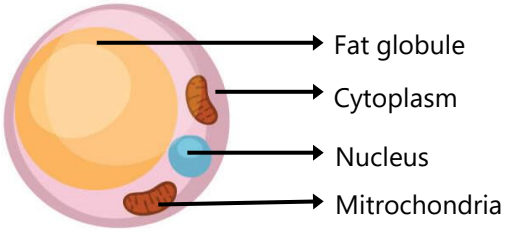
(B) ADIPOSE CONNECTIVE TISSUE :

- Adipose tissue is another type of loose connective tissue located mainly beneath the skin.
- It contains adipocytes / fat cells abundantly.
- The cells are specialised to store fats, the excess of nutrients which are not used immediately are converted into fats and are stored in this tissue.



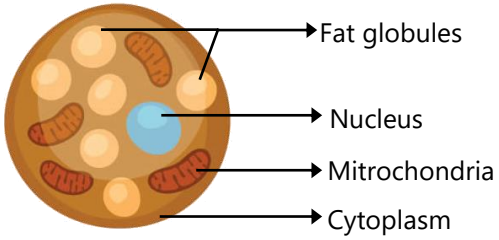
- On the basis of adipocytes 2 type of fats are found in animals.
  1. White fat 2. Brown fat

1. **White fat :-** It is composed of monolocular adipocytes in which single large fat globule and less number of mitochondria are present. So they produce less energy.
   e.g. - Panniculas adiposus :- A thin continuous layer of white fat under the dermis of skin which is also called **hypodermis** of skin.



Yellow bone marrow, Fat bodies of frog, Blubber of whale, Hump of camel

2. **Brown fat :-** It is composed of multilocular adipocytes in which many fat globules are present and due to more number of mitochondria it produces 20 times more energy than white fat.
   e.g. Cold resistance device in new born baby is due to presence of brown fat.



Question-1: White adipose tissue contains?

(1) Multilocular fat cells (2) Bilocular fat cells
(3) Unilocular fat cells (4) Alocular fat cells

Answer: (3) Unilocular fat cells

Question-2: The connective tissue that connects the skin to the underlying structures is –

(1) Areolar tissue (2) Dense regular connective tissue
(3) Reticular tissue (4) Dense irregular connective tissue

Answer: (1) Areolar tissue

Question-3: Hump of Camel is made up of –

(1) Skeletal tissue (2) Muscular tissue (3) Areolar tissue (4) Adipose tissue

Answer: (4) Adipose tissue

Question-4: The most widely distributed connective tissue in the body is –

(1) Dense regular connective tissue (2) Cartilage

(3) Areolar tissue (4) Adipose tissue

Answer: (3) Areolar tissue

SPECIALISED CONNECTIVE TISSUE :

Specialised C.T.

Skeletal C.T. — **Matrix solid and mineralised**
e.g. – Cartilage and´ bone

Fluid C.T. — **Liquid and fibre free matrix**
e.g. – Blood and lymph

SKELETON CONNECTIVE TISSUE :

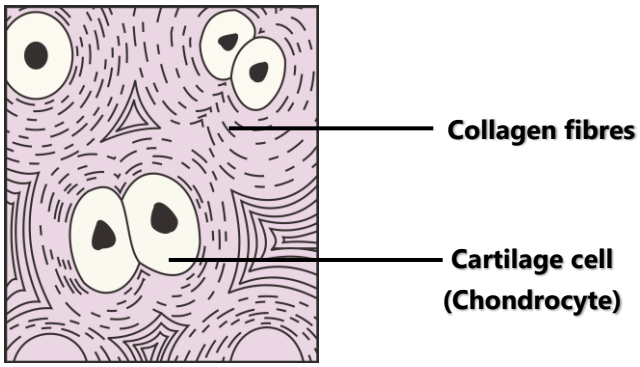
- Matrix is dense & mineralised. Due to deposition of minerals it becomes hard.
- Also known as **Supporting Tissue** i.e. Provide support to the body.
- It is of 2 types
  1. Cartilage
  2. Bone

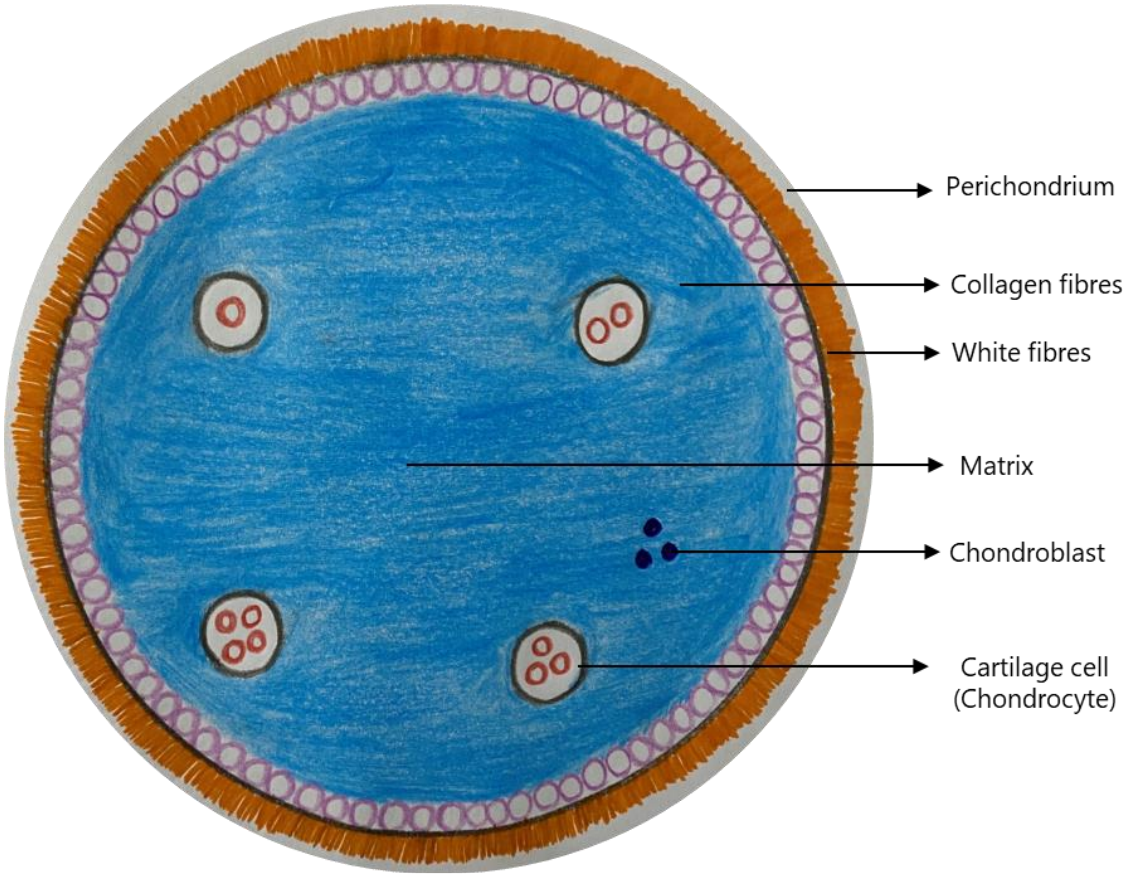
CARTILAGE :

- Most of the cartilages in vertebrate embryos are replaced by bones in adults
- Outer most covering of cartilage is called **Perichondrium** which is composed of white fibrous connective tissue.
- **Matrix (inter-cellular materials) is solid, pliable and can resists compression.**
- Cartilage producing cells are arranged on periphery of cartilage known as **Chondroblast**.
- These are active cells & divide to form chondrocytes, and synthesize the matrix of cartilage.
- Cells of this tissue (Chondrocytes) are enclosed in small cavities (Lacunna), with in the matrix secreted by them.
- **Chondroclast** are cartilage destroying cells.

Matrix of cartilage provides rigidity & elasticity to cartilage.

e.g. - Cartilage is present in the tip of nose, outer ear joints, between adjacent bones of the vertebral column, limbs and hands in adults.





CARTILAGE

HYALINE CARTILAGE :

- It is the most common cartilage of human body.
- Most of the part of embryonic skeleton is composed of this cartilage. So maximum bones of our body are cartilaginous bones because they are developed from cartilage.
- Matrix of this cartilage is glass like clear or hyaline Matrix because fibres are completely absent.
- Colour of matrix is bluish & it is translucent (less transparent).

e.g. Nasal septum.

'C' shaped rings of trachea and bronchi. Sternal part of ribs. (Costal cartilage)

Laryngeal cartilage :- Maximum part of larynx is composed of Hyaline cartilage.

Articular cartilage :- At he end of long bone periosteum is Absent and Hyaline cartilage is present known as Articular Cartilage.

ELASTIC CARTILAGE :

- In the matrix of this cartilage yellow fibres form network so it is highly flexible cartilage of our body.

e.g. Tip of Nose
Ear Pinna
Larynx – Epiglottis and Cartilage of Santorini of larynx
Wall of eustachian tube

WHITE FIBROUS CARTILAGE :

- Perichondrium is absent because complete WFCT is converted into cartilage.
- In matrix bundle of collagen fibres are more in quantity so it is Strongest cartilage.
  e.g. – Pubic symphysis – Connects both the pelvic halves with each-other.
  Intervertebral disc – A pad of cushion like structure which absorb mechanical shock & jerks and protect vertebral column.
- Central part of intervertebral disc is soft called Nucleus pulposus.

CALCIFIED CARTILAGE :

- It is modified hyaline cartilage but due to deposition of calcium salts its matrix becomes hard like bones **(hardest cartilage)**
- Ca^{++} salt deposits in the form of Hydroxy in the form of Hydroxy apatite.
  e.g. Pubis of frog's pelvic girdle.
  Head of femur and humerus.

Question-1: Outer most covering of cartilage is called –

(1) Chondroblast (2) Perichondrium (3) Osteoblast (4) Chondroclast

Answer: (2) Perichondrium

Question-2: Matrix of cartilage is –

(1) hollow, pliable and can resists compression
(2) solid, pliable and can resists compression
(3) solid, pliable and can not resists compression
(4) solid, non-pliable and can resists compression

Answer: (2) solid, pliable and can resists compression

Question-3: In human beings cartilages are found –

(1) Tip of nose
(2) Outer ear joints
(3) Between adjacent bones of the vertebral Column
(4) All of these

Answer: (4) All of these

Question-4: Which of the following is cartilage is destroying cells?

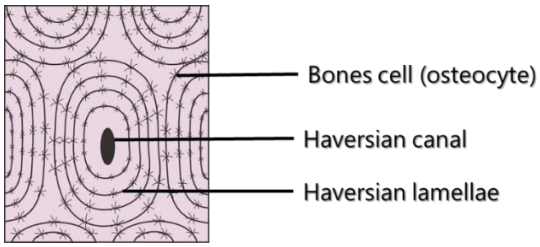
(1) Perichondrium (2) Osteoblast (3) Chondroclast (4) Chondroblast

Answer: (3) Chondroclast

BONE :

- Outermost covering of bone is **Periosteum** composed of white fibrous connective tissue.
- Bone producing cell is called **Osteoblast.** They divide to form **Osteocyte** & synthesize organic part of matrix.
- Mature cell of bone is called **Osteocyte** which is found in lacuna. Only one osteocyte is found in one lacuna.
- Bone destroying cells are called **Osteoclast** cells.
- Process of bone formation is called OSSIFICATION.
- Bones have a **hard and non-pliable ground substance rich in Ca-salts and collagen fibres** which gives bone its strength.

- Study of bones is called osteology.

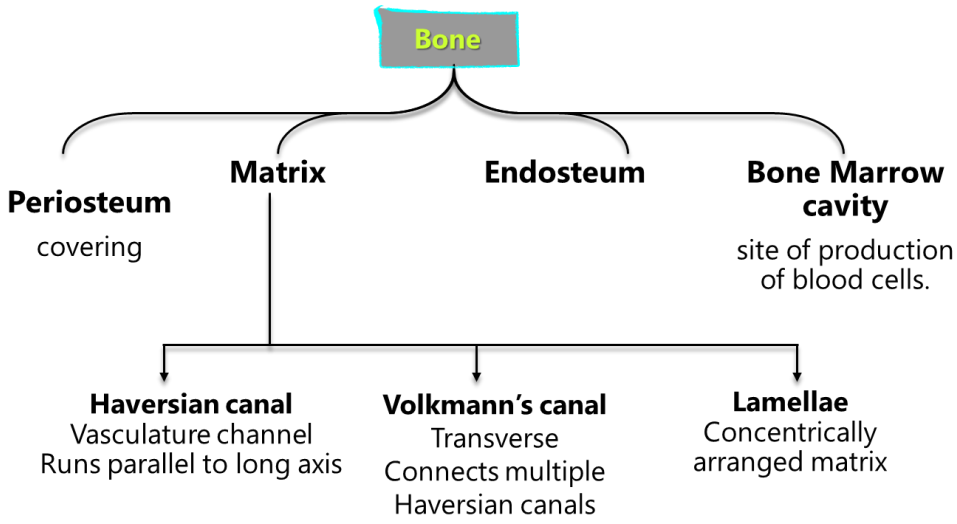


FEATURES OF BONES :

1. It is highly vascular.
2. It is mineralised.
3. It is hard and rigid.
4. It has a canalicular systems.
5. It has a regenerating capacity.

FUNCTIONS OF BONE :

(1) It is the main tissue that provide structural framework to the body.
(2) Bones support and protect softer tissues and organs.
(3) Limb bones, such as the long bones of the legs, serve weight bearing functions.
(4) They also interact with skeletal muscles attached to them, to bring about movements.
(5) The bone marrow in some bones is the site of production of blood cells.



STRUCTURE OF LONG BONE :

- Limb bones, such as long bones of the legs serve weight bearing functions.
- Long bone has three region.

(i) Epiphysis

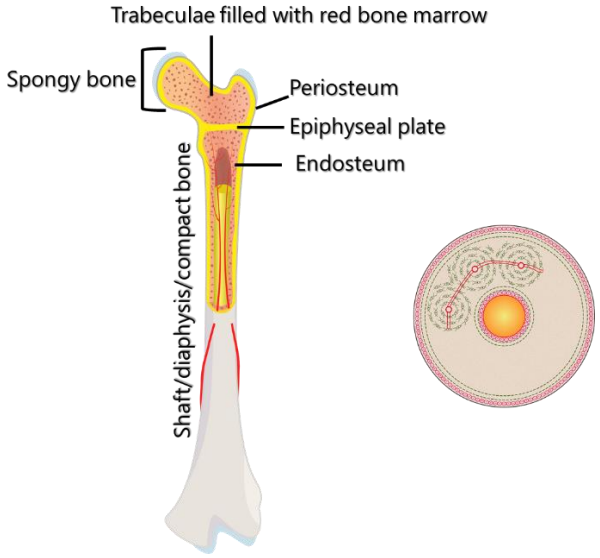
- Ends of long bone is called **Epiphysis**. This part is composed of spongy tissue.
- Cavity is present in the form of **trabeculae** filled with red bone marrow which is the site of production of blood cells.

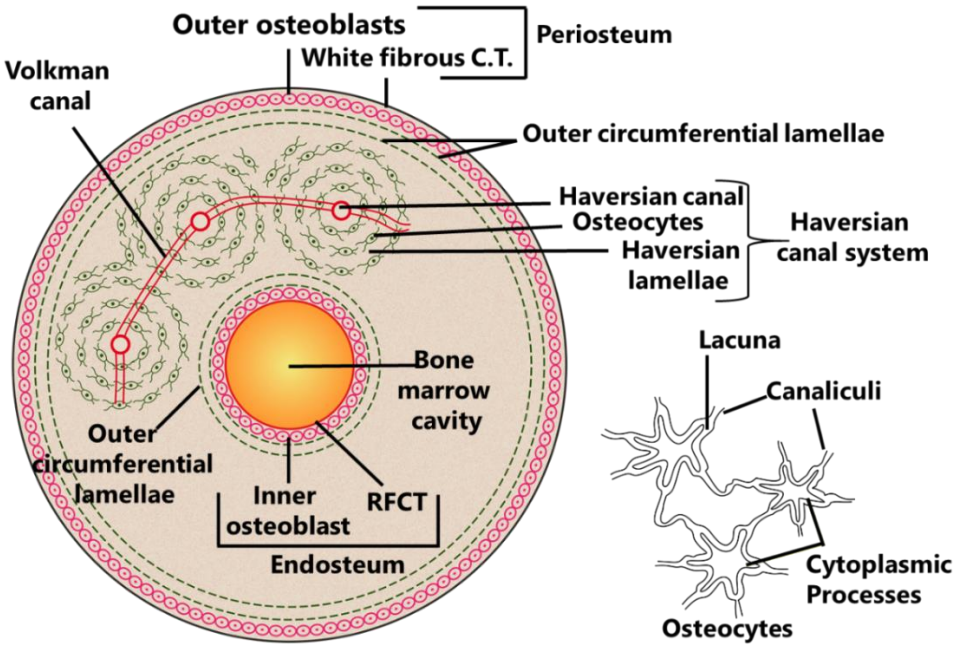
(ii) Diaphysis

- Middle part or shaft of long bone is diaphysis which is composed of **compact bone**.
- In this region hollow cavity is present called bone marrow cavity filled with yellow bone marrow composed of white fat and matrix contain Haversian systems.

(iii) Metaphysis

- It is a small part between epiphysis & Diaphysis.
- In this region **epiphyseal plate** is present which is made up of osteoblast cells. It is responsible for elongation of bone.
- After complete development of long bone this plate is destroyed.





INTERNAL STRUCTURE OF MAMMALIAN BONE :

It has following major structures.

1. Periosteum
2. Matrix
3. Endosteum
4. Bone marrow cavity

1. PERIOSTEUM

- It consists of two layers.
- Outer layer consist of WFCT in which blood circulation is present.
- Inner layer - consists of single layer of osteoblast cells, which divide to form osteocyte and secrete layers of matrix.

2. MATRIX

It is composed of inorganic & organic compounds.

Inorganic Part :- 65 - 68%

$Ca_3(PO_4)_2$ – 80% max, $CaCO_3$ (10%), $Mg_3(PO_4)_2$ (10%), Flourides (very less).

Organic part :- 32 - 35% Ossein (protein component of Bone.) in which bundle of collagen fibres suspended in sulphated mucopolysaccharide.

(i) HAVERSIAN CANAL

- Longitudinal canals which are arranged parallel to long axis of bone. In these canals one or two blood capillaries and nerve fibres are present.

(ii) VOLKMANN'S CANAL

- These are transverse/horizontal or oblique canals. Haversian canals are interconnected by volkmann's canal.

(iii) LAMELLAE

- Matrix of bone is deposited in the form of layer. These layers of matrix are called **Lamellae.**
- On the basis of arrangement three types of lamellae are present in the matrix.
  - (1) Haversian lamellae
  - (2) Interstitial lamellae
  - (3) Circumferential lamellae.

(1) HAVERSIAN LAMELLAE

- Concentric layers of matrix which are present around Haversian canal.
- Between these lamellae layer of osteocyte cells are also present.
- Haversian canal, Haversian lamellae & Osteocyte form **Haversian** system or **Osteon**.
- Presence of Haversian system is a typical feature of **mammalian** compact bones.
- Osteocyte are present in the lacuna. Each osteocyte is inter connected with adjacent osteocyte by their cytoplasmic process.
- Cytoplasmic process of osteocyte are present in the minute canals of lacuna called as **canaliculi**.

(2) INTERSTITIAL LAMELLAE

- These layers of matrix are present in the space between two Haversian systems.

(3) CIRCUMFERENTIAL LAMELLAE

- Peripheral layer of matrix present just below the periosteum and around the bone marrow cavity.

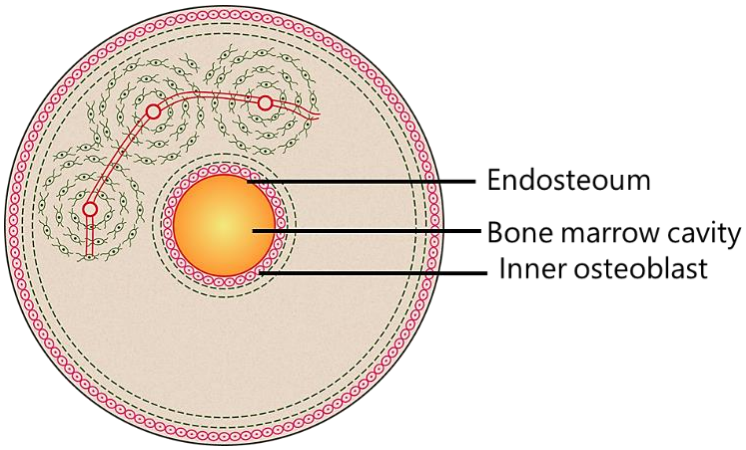
3. ENDOSTEUM

Endosteum consist of two layers.

1. Towards bone marrow cavity layer lined with reticular fibrous connective tissue.
2. Towards matrix of bone endosteum lined with layer of osteoblast cells. They divide to form osteocyte & synthesize matrix. So growth of bone is bidirectional (Periphery & central region). While Growth of cartilage is unidirectional.

4. BONE MARROW CAVITY

- In the central region hollow cavity is present which is filled with yellow bone marrow.



Question-1: Process of bone formation is called –

(1) Ossification (2) Osteoblastic deposition
(3) Osseointegration (4) Osteocytic maturation

Answer: (1) Ossification

Question-2: which of the following is not the function of bone?

(1) Structural frame to the body
(2) Support and protect softer tissues and organs
(3) Weight bearing functions.
(4) All

Answer: (4) All

Question-3: In a Compact bone, Haversian Canals are found in –

(1) Cartilage (2) Bone marrow (3) Bone matrix (4) Fibrous cartilage

Answer: (3) Bone matrix

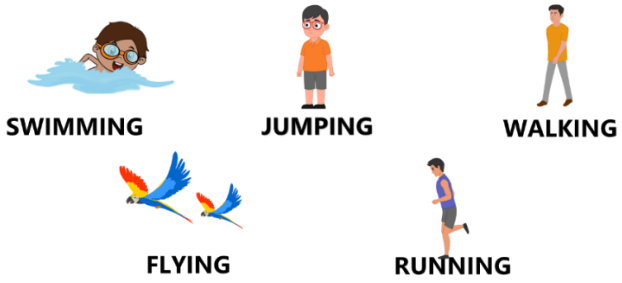
Question-4: identify the correct labelling-

	A	B
(1)	metaphysis	diaphysis
(2)	diaphysis	transphysis
(3)	epiphysis	metaphysis
(4)	transphysis	epiphysis

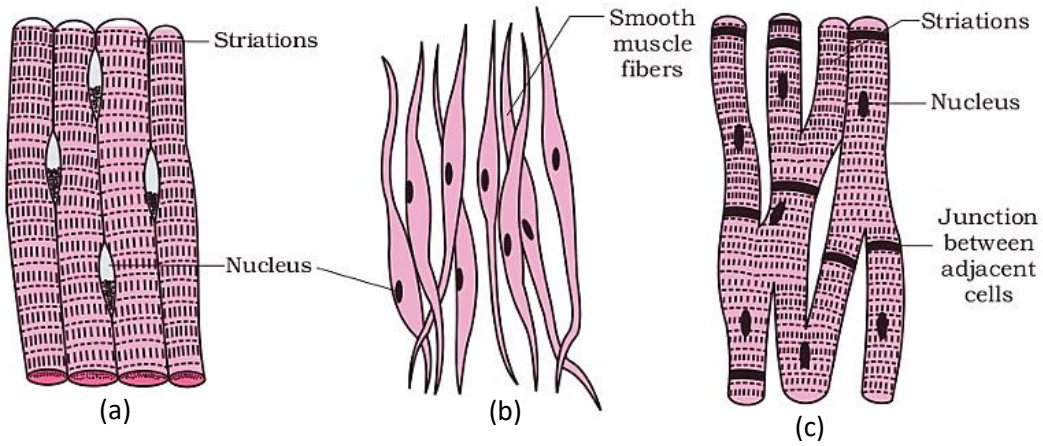
Answer: (1) metaphysis - diaphysis

MUSCLE TISSUE :

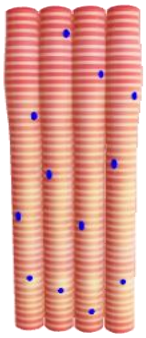
- Each muscle is made of many long, cylindrical fibres arranged in parallel arrays.
- These fibres are composed of numerous fine fibrils, called myofibrils.
- Muscle fibres contract (shorten) in response to stimulation, then relax (lengthen) and return to their uncontracted state in a coordinated fashion.
- Their action moves the body to adjust to the changes in the environment and to maintain the positions of the various parts of the body.



- In general, muscles play an active role in all the movements of the body. Muscles are of three types, skeletal, smooth, and cardiac.

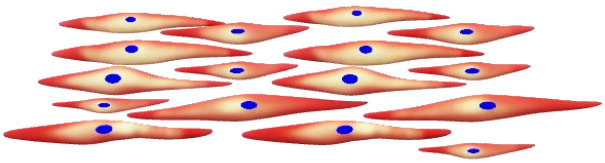


- **Skeletal muscle** tissue is closely attached to skeletal bones. In a typical muscle such as the biceps, striated (striped) skeletal muscle fibres are bundled together in a parallel fashion.
- A sheath of tough connective tissue encloses several bundles of muscle fibres.

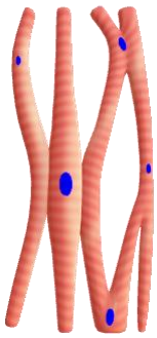


- The **smooth muscle** fibres taper at both ends (fusiform) and do not show striations. Cell junctions hold them together and they are bundled together in a connective tissue sheath.
- The wall of internal organs such as the blood vessels, stomach and intestine contains this type of muscle tissue.

- Smooth muscles are 'involuntary' as their functioning cannot be directly controlled.
- We usually are not able to make it contract merely by thinking about it as we can do with skeletal muscles.



- **Cardiac muscle** tissue is a contractile tissue present only in the heart. Cell junctions fuse the plasma membranes of cardiac muscle cells and make them stick together.
- Communication junctions (intercalated discs) at some fusion points allow the cells to contract as a unit, i.e., when one cell receives a signal to contract, its neighbours are also stimulated to contract.



Question-1: Arrangement of fibers in Muscle tissue are –

(1) single long, cylindrical fibres arranged in parallel arrays
(2) many long, round fibres arranged in parallel arrays
(3) many long, cylindrical fibres arranged in parallel arrays
(4) few long, round fibres arranged in parallel arrays

Answer: (3) many long, cylindrical fibres arranged in parallel arrays

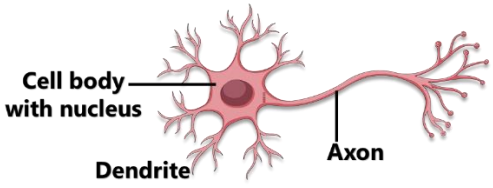
Question-2: Which of the following is not the function of muscular tissue in body?

(1) All the movements
(2) Formation of RBC's
(3) Maintain the positions of the various parts of the body
(4) Locomotion

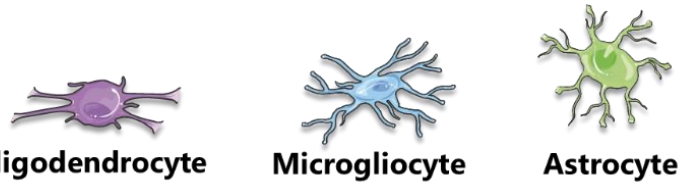
Answer: (2) Formation of RBC's

NERVOUS TISSUE :

- Neural tissue exerts the greatest control over the body's responsiveness to changing conditions.
- Neurons, the unit of neural system are excitable cells.



- The neuroglial cell which constitute the rest of the neural system protect and support neurons.
- Neuroglia make up more than one half the volume of neural tissue in our body.



- When a neuron is suitably stimulated, an electrical disturbance is generated which swiftly travels along its plasma membrane.
- Arrival of the disturbance at the neuron's endings, or output zone, triggers events that may cause stimulation or inhibition of adjacent neurons and other cells.

Question-1: A structural and functional unit of nervous system is –

(1) axon (2) synapse (3) nerve fibre (4) neuron

Answer: (4) neuron

Question-2: Which of the following is the function of neuroglial cells?

(1) Generation of nerve impulse (2) Conduction of nerve impulse

(3) Transmission of nerve impulse (4) Protect and support nerve cells

Answer: (4) Protect and support nerve cells

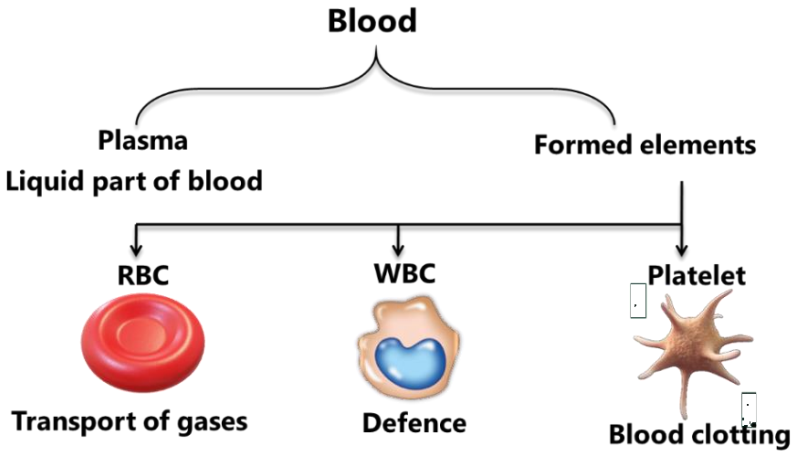
BLOOD :

- Blood is a fluid connective tissue containing plasma, red blood cells (RBC), white blood cells (WBC) and platelets.
- It is the main circulating fluid that helps in the transport of various substances.

FUNCTIONS :

Transport of gases and nutrients.

- Blood is the medium of transport for O_2 and CO_2.
- O_2 binds with haemoglobin as – Oxyhaemoglobin.
- CO_2 binds with haemoglobin as – Carbaminohaemoglobin.



Question-1: Oxygen combines with haemoglobin to form –

(1) Oxyhaemoglobin (2) Carboxyhaemoglobin
(3) Carbaminohaemoglobin (4) All of the above

Answer: (1) Oxyhaemoglobin

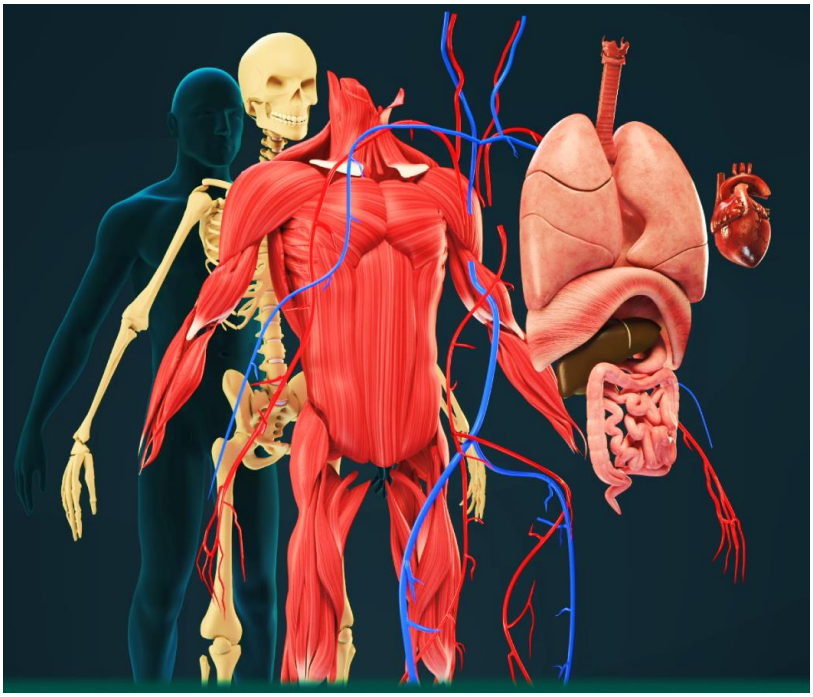
Question-2: Which of the following components of blood helps in blood clotting?

(1) Blood platelets (2) R.B.C (3) W.B.C (4) Plasma

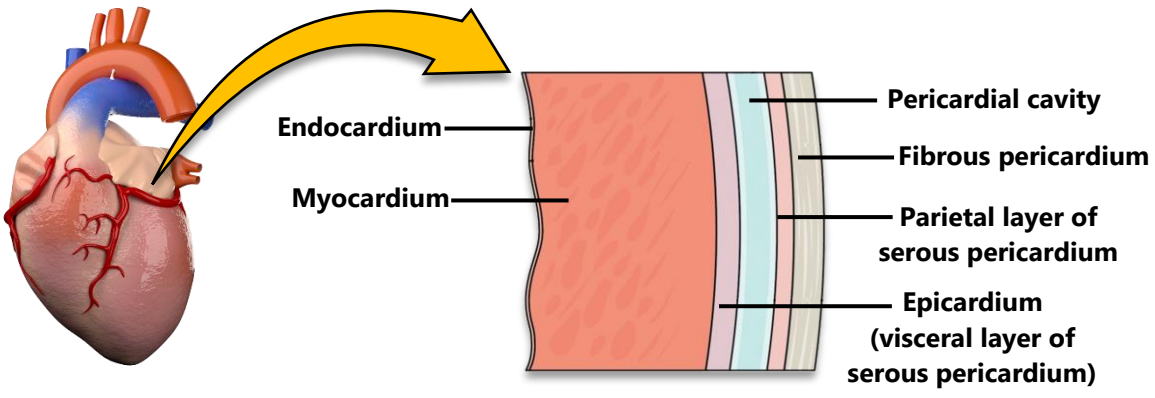
Answer: (1) Blood platelets

ORGAN AND ORGAN SYSTEM :

- The basic tissues mentioned above organise to form organs which in turn associate to form organ systems in the multicellular organisms.
- Such an organisation is essential for more efficient and better coordinated activities of millions of cells constituting an organism.



- Each organ in our body is made of one or more type of tissues. For example, our heart consists of all the four types of tissues, i.e., epithelial, connective, muscular and neural.



- Morphology refers to study of form or externally visible features.
- In the case of plants or microbes, the term morphology precisely means only this.
- In case of animals this refers to the external appearance of the organs or parts of the body.
- The word anatomy conventionally is used for the study of morphology of internal organs in the animals.

Question-1: The basic tissues organise to form–

(1) organs (2) cells

(3) organ system (4) mineral system

Answer: (1) organs

Question-2: Morphology in plants refer to study of –

(1) Internal features (2) Relation with microbes

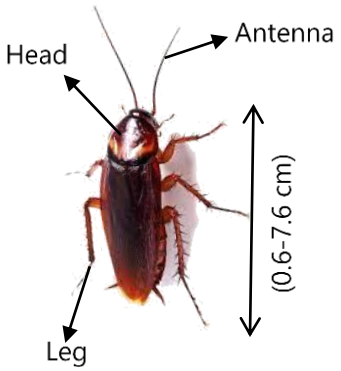
(3) Association with other plants (4) External features

Answer: (4) External features

Periplaneta americana (COCKROACH)

INTRODUCTION :

- Cockroaches are brown or black bodied animals.
- Bright yellow, red and green coloured cockroach have also been reported in tropical regions.
- Cockroaches are included in **class Insecta** of **Phylum Arthropoda**.
- Their size ranges from ¼ inches to 3 inches (0.6-7.6 cm) and have long antenna, legs and flat extension of the upper body wall that conceals head.



- They are **nocturnal omnivores** that live in damp places throughout the world.
- Cockroaches are **cursorial insects**, i.e., they run very fast.
- They have become residents of human homes.
- Cockroaches are serious pests and vectors of several diseases like :-
  (i) Typhoid fever
  (ii) Cholera
  (iii) Dysentery
  (iv) Giardiasis

Question-1: Cockroach belongs to class _____of phylum arthropoda.

(1) Crustacea
(2) Arachnida
(3) Insecta
(4) Myriapoda

Answer: (3) Insecta

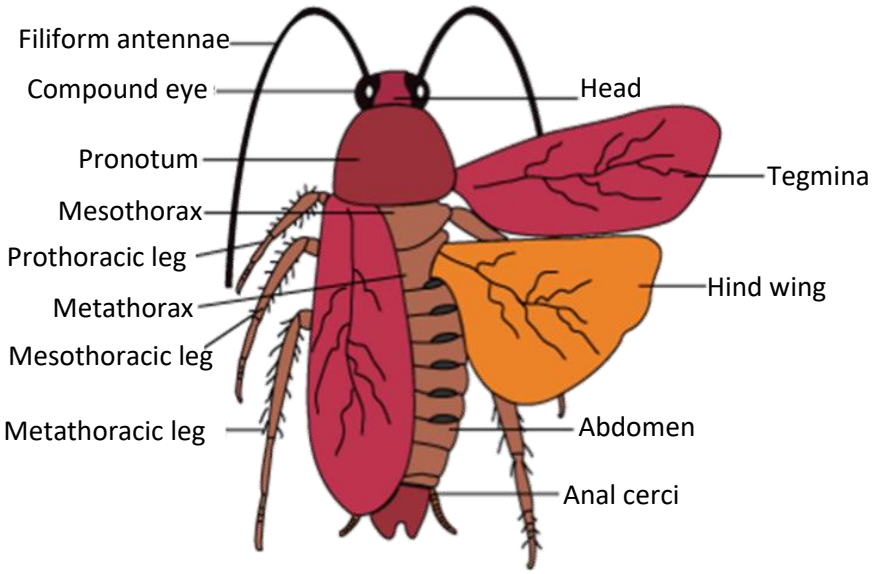
Question-2: Size of cockroach is :-

(1) from 3 cm to 15 cm
(2) from 0.6 cm to 7.6 cm
(3) from 7.6 cm to 20 cm
(4) from 1 cm to 3 cm

Answer: (2) from 0.6 cm to 7.6 cm

MORPHOLOGY :

- The adults of the common species of cockroach, ***Periplaneta americana*** are about **34-53 mm long** with wings that extend beyond the tip of the abdomen in males.
- The body of the cockroach is segmented and divisible into three distinct regions – head, thorax and abdomen.



External features of Cockroach

- The entire body is covered by a hard **chitinous exoskeleton** (brown in colour).
- In each segment, exoskeleton has hardened plates called **sclerites** (**tergites dorsally, sternites ventrally** and **pleurites laterally**) that are joined to each other by a thin and flexible **articular membrane (arthrodial membrane)**.
- The arthrodial membrane that joins the **5th and 6th tergites** bears a pair of **scent glands** whose secretion probably helps in repelling enemies. According to some entomologists, these glands occur only in males and secrete, in breeding season, a scent that excites the females for copulation.

ANATOMY :

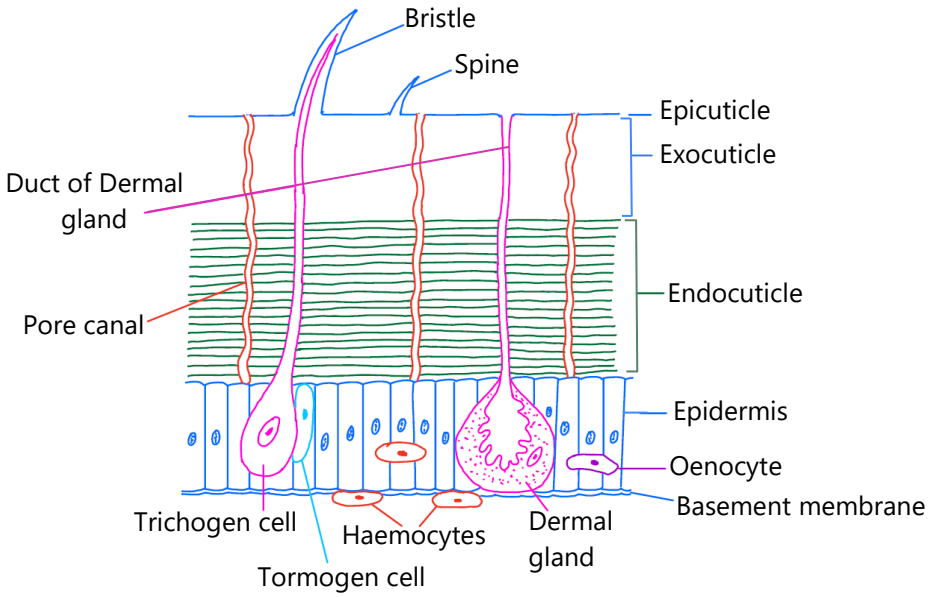
BODY WALL :

- Body wall of cockroach consists of the following 3 layers :-

  (i) Cuticle

  (ii) Epidermis (Hypodermis)

  (iii) Basement membrane



T.S. Body wall of Cockroach

- Cuticle forms the outermost layer, secreted by the epidermis. It is chitinous. It consists of
  (a) Epicuticle :- Outer, thin and waxy layer
  (b) Exocuticle :- Middle, tough, chitinous and pigmented layer
  (c) Endocuticle :- Thick and innermost layer
- Epidermis contains :-
  (a) Trichogen cells :- Secrete movable bristles
  (b) Tormogen cells :- Secrete membranes around the bristles
  (c) Dermal gland :- Secrete waxy substance with gives obnoxious smell
  (d) Oenocytes :- Help in epicuticle formation and also influence moulting
- Basement membrane lies below the epidermis.

Question-1: In each segment, exoskeleton has hardened plates called _____, _____ dorsally and _____ ventrally.

(5) sclerites, tergites, sternites
(6) tergites, sclerites, sternites
(7) tergites, sternites, sclerites
(8) sternites, tergites, sclerites

Answer: (1) sclerites, tergites, sternites

Question-2: The entire body is covered by a hard exoskeleton made up of :-

(1) Cellulose
(2) Chitin
(3) Glycogen
(4) Glucose

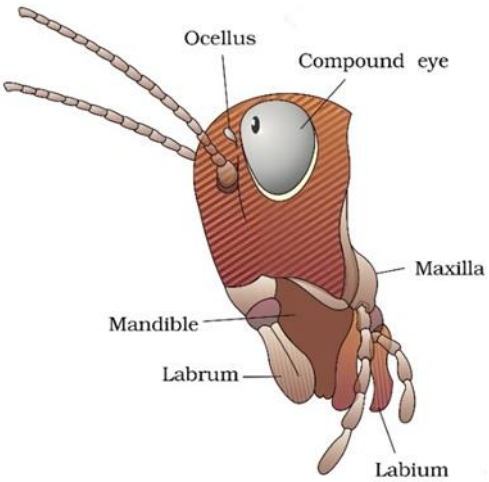
Answer: (2) Chitin

HEAD :

- Head is triangular in shape and lies anteriorly at **right angles** to the longitudinal body axis **(hypognathous)**.

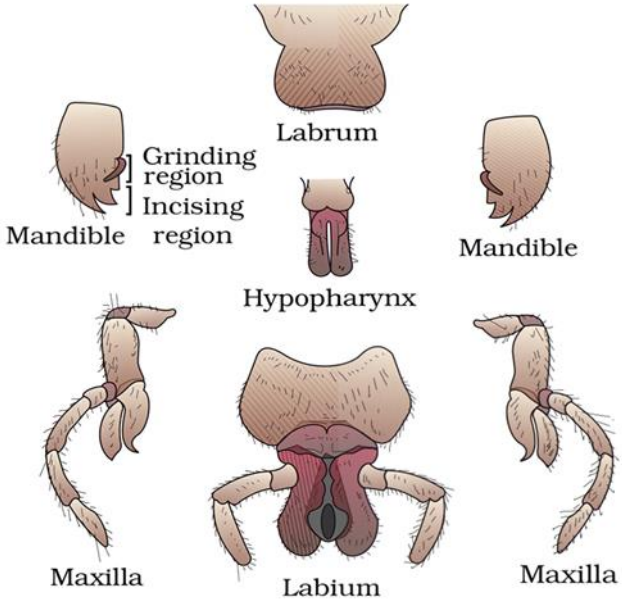
Triangular head at 90^0 to longitudinal axis of body

- It is formed by the fusion of six segments and shows great mobility in all directions due to **flexible neck**.



Head region of cockroach

- In adult all sclerites of the head are fused to from a **head capsule**. The head capsule bears a pair of **compound eyes**.
- A pair of thread like **antennae** arise from membranous sockets lying in front of eyes.
- Anterior end of the head bears appendages forming biting and chewing type of mouth parts.
- The **mouthparts** consisting of a labrum (upper lip), a pair of mandibles, a pair of maxillae and a labium (lower lip).
- A median flexible lobe, acting as tongue (hypopharynx), lies within the cavity enclosed by the mouthparts.
- Antennae have sensory receptors that help in monitoring the environment.



Mouth parts of cockroach

Question-1: Head of cockroach is _____ in shape and lies anteriorly at _____ angles to the longitudinal body axis.

(1) triangular, acute (2) triangular, obtuse (3) triangular, right (4) circular, right

Answer: (3) triangular, right

Question-2: A median flexible lobe, acting as tongue (_____), lies within the cavity enclosed by the mouthparts.

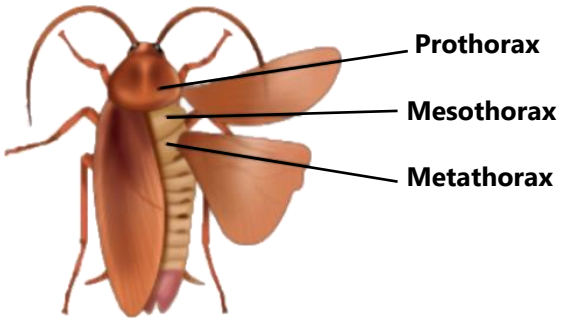
(1) hyperpharynx (2) hypopharynx (3) labial palp (4) maxilla

Answer: (2) hypopharynx

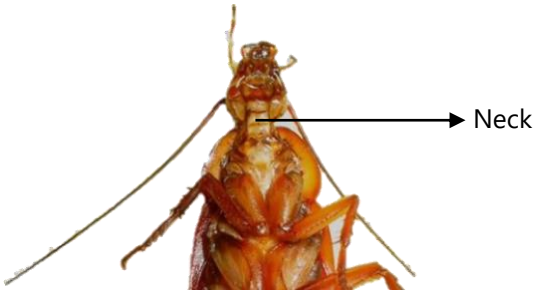
THORAX AND ABDOMEN :

THORAX :

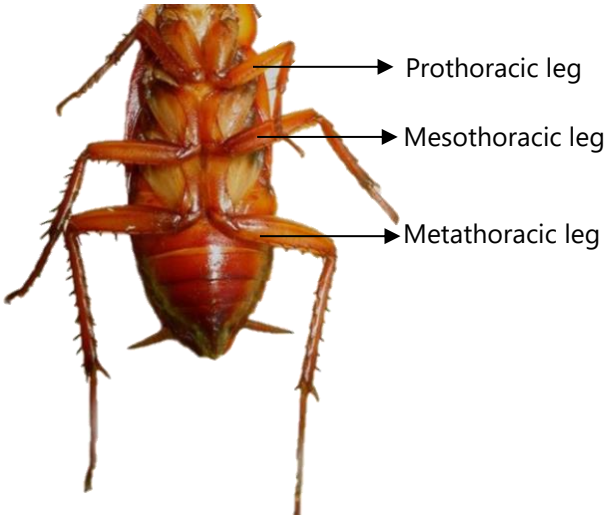
- Thorax consists of three parts – **prothorax, mesothorax** and **metathorax**.



- The head is connected with thorax by a short extension of the prothorax known as the **neck**.



- The thorax bears **three pairs of legs** and **two pairs of wings**.



- Each **leg** is composed of five **podomeres** -

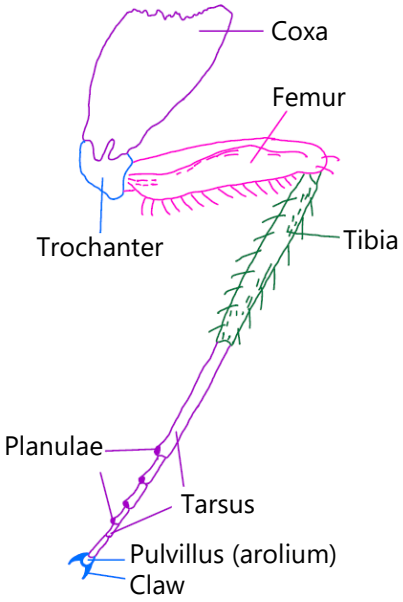
(i) Coxa

(ii) Trochanter

(iii) Femur

(iv) Tibia

(v) Tarsus



Leg of cockroach

- Two pairs of wings are found in cockroach.
- The **first pair** of wings arises from mesothorax and the **second pair** from metathorax.

Mesothoracic wings (tegmina) /Fore wings

Opaque dark and leathery and cover the hind wings when at rest

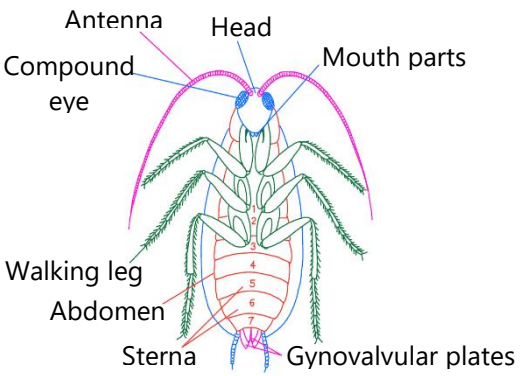
Metathoracic wings/Hind wings

Transparent, membranous and are used in flight.

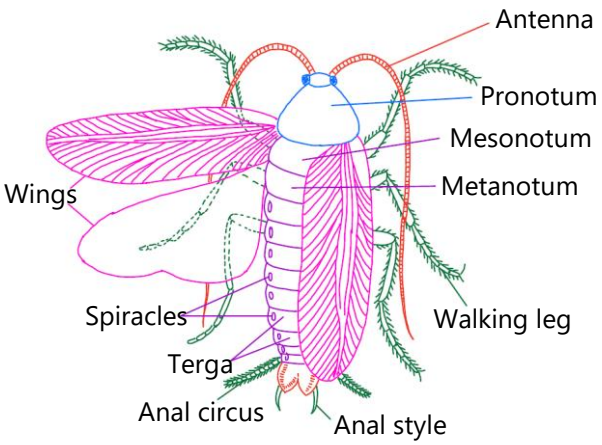
- **Forewings (mesothoracic)** called **tegmina** are opaque dark and leathery and cover the hind wings when at rest. The **hind wings (metathoracic)** are transparent, membranous and are used in flight.

ABDOMEN :

- The abdomen in **both males** and **females** consists of **10 segments**.

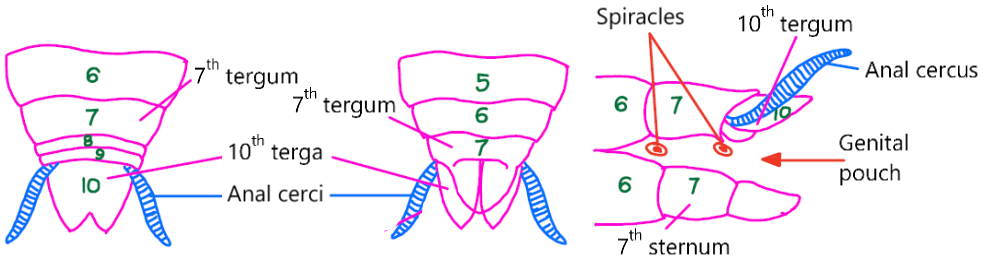


Female cockroach



Male cockroach (Dorsal view)

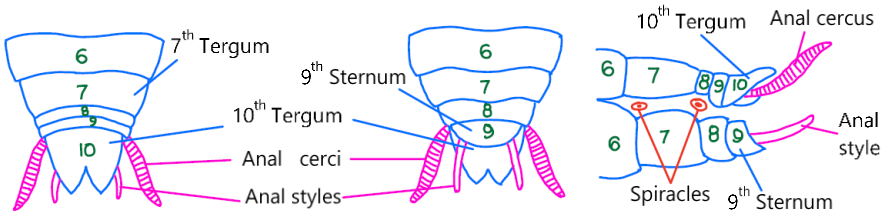
- **In females**, the **7th sternum is boat shaped** and together with the 8th and 9th sterna forms a **brood** or **genital pouch** whose anterior part contains **female gonopore**, **spermathecal pores** and **collateral glands**.



(a) Dorsal view **(b) Ventral view** **(C) Lateral view**

Posterior segment of female cockroach

- **In males**, genital pouch or chamber lies at the hind end of abdomen bounded dorsally by 9th and 10th terga and ventrally by the 9th sternum.
- It contains dorsal anus, ventral **male genital pore** and **gonapophysis**.



(a) Dorsal view **(b) Ventral view** **(c) Lateral view**

Posterior segment of male cockroach

- Males bear a pair of short, threadlike **anal styles** which are absent in females.
- In both sexes, the 10th segment bears a pair of jointed filamentous structures called **anal cerci**.

Question-1: Identify the correct labelling-

(1) Fore leg
(2) Thoracic leg
(3) Mesothoraic leg
(4) Prothoracic leg

Answer: (4) Prothoracic leg

Question-2: Second pair of wings in cockroaches arises from -

(1) Pronotum (2) Metathorax (3) Mesothorax (4) Prothorax

Answer: (2) Metathorax

Question-3: Identify the wrong statement :-

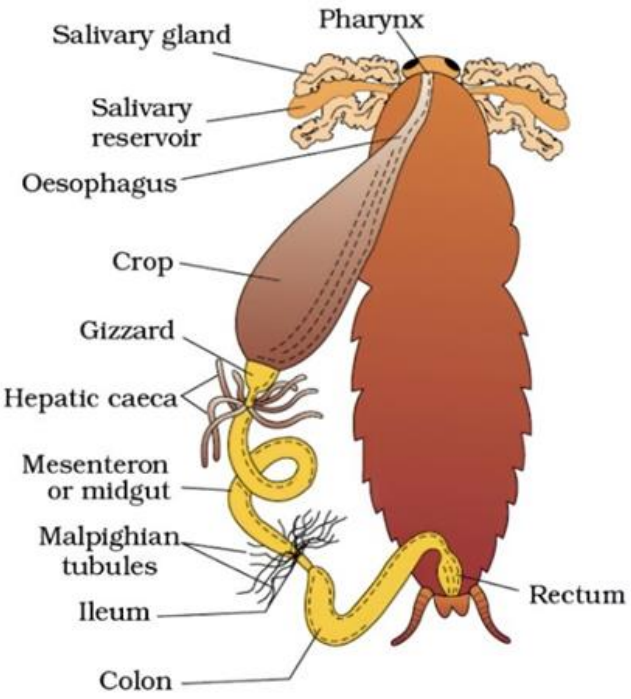
(1) Males bear a pair of short, thread like anal styles
(2) Males have anal styles which are absent in females
(3) Males do not have anal styles which are present in females
(4) Anal styles are present in both male and females

Answer: (3) Males do not have anal styles which are present in females

ANATOMY :

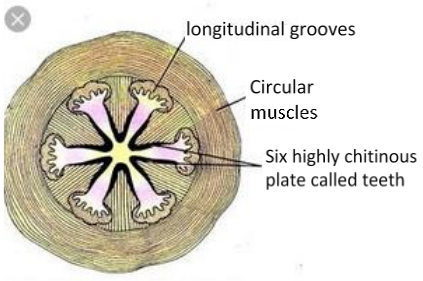
DIGESTIVE SYSTEM :

- The alimentary canal present in the body cavity is divided into three regions:-
  (i) Foregut (Stomodaeum) **(ii) Midgut (Mesenteron)** **(iii) Hindgut (Proctodaeum)**
- Foregut comprises the **preoral cavity, mouth, pharynx, oesophagus, crop** and **gizzard**.
- The **mouth** opens into a short tubular **pharynx**, leading to a narrow tubular passage called **oesophagus**.



Alimentary canal of cockroach

- This in turn opens into a sac like structure called **crop** used for storing of food. **Most of the food is digested in the crop.**
- The crop is followed by **gizzard** or **proventriculus**. It has an outer layer of thick circular muscles and thick inner cuticle forming **six highly chitinous plate** called **teeth**.
- Gizzard helps in grinding the food particles.
- The **entire foregut is lined by cuticle**.

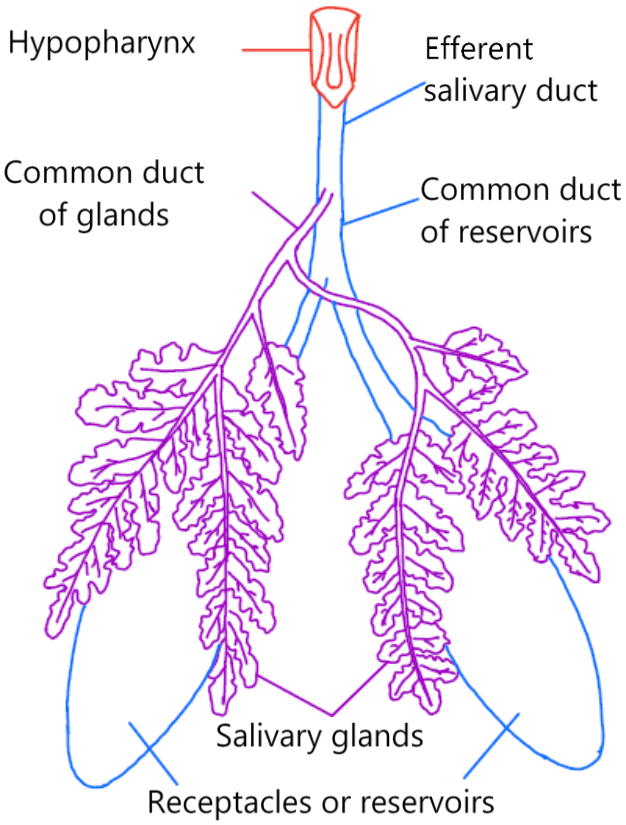


Gizzard

- **Midgut** is thin walled coiled tube with almost uniform thickness. A **peritrophic membrane** is formed around the food in the midgut, which is permeable to digestive enzymes and digested foods.
- A ring of **6-8 blind tubules** called **hepatic** or **gastric caeca** is present at the junction of foregut and midgut, which secrete digestive juice.

Gastric or Hepatic caeca

- At the junction of midgut and hindgut is present another ring of **100-150 yellow coloured** thin filamentous Malpighian tubules. They help in removal of excretory products from haemolymph.
- The hindgut is broader than midgut and is differentiated into **ileum, colon** and **rectum**.
- The rectum opens out through **anus**.
- Cockroach has **paired salivary glands** lying one on each side of the oesophagus and crop.
- Salivary glands secrete **saliva** which contains **amylase, chitinase** and **cellulase enzymes**.



Salivary apparatus of cockroach

Question-1: Which of the following is the correct function of crop in cockroach?

(1) Grinding of food
(2) Cutting of food
(3) Storage of food
(4) All of the above

Answer: (3) Storage of food

Question-2: The haemolymph helps in removal of -

(1) Excretory products
(2) Digestive products
(3) Respiratory products
(4) Circulatory products

Answer: (1) Excretory products

ANATOMY :

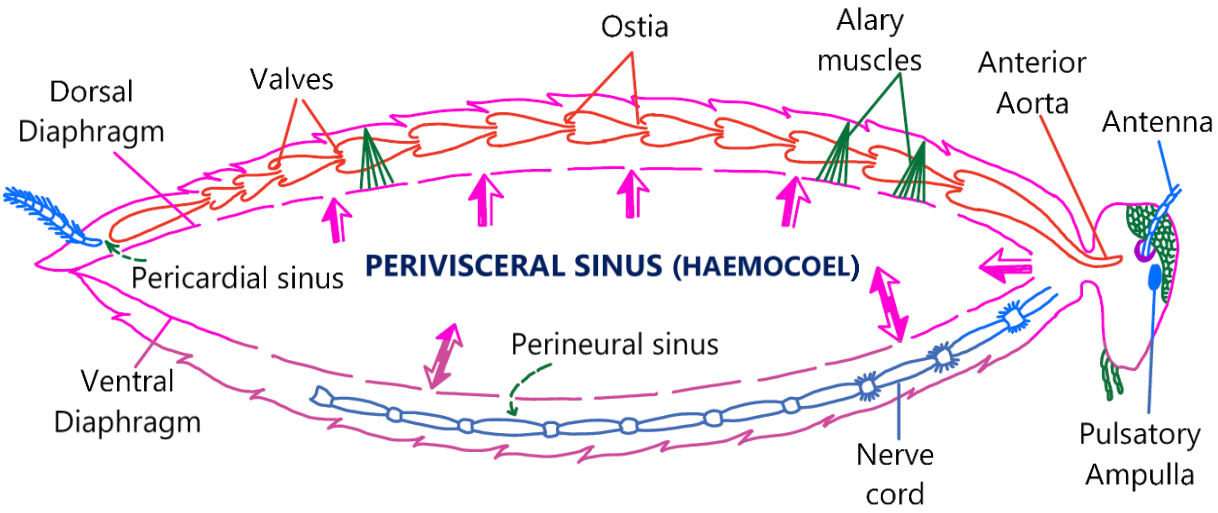
CIRCULATORY SYSTEM :

- Blood vascular system of cockroach is an **open type**.
- Blood vessels are poorly developed and open into space **(haemocoel)**. Two horizontal partitions **(diaphragms)**, divide the heamocoel into three **large spaces** :-

  (i) Dorsal or pericardial sinus :- It encloses the heart.

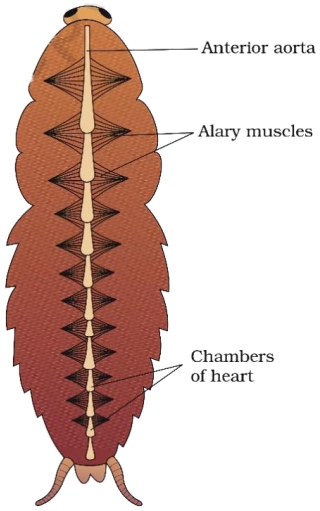
  (ii) Middle or perivisceral sinus :- It encloses most of the viscera.

  (iii) Vental or perivisceral sinus :- It encloses nerve cord.

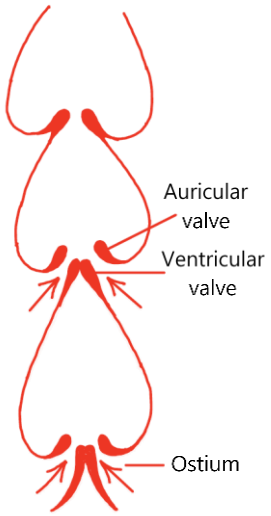


Blood vascular system of cockroach

- Both the diaphragms are **perforated by a number of apertures** through which all the three sinuses are inter-connected.
- Some blood-filled spaces are also found in the head (**head sinuses**).
- Visceral organs located in the haemocoel are bathed in **blood (haemolymph)**.
- The haemolymph is composed of **colourless plasma** and **haemocytes**.
- **Heart** of cockroach consists of **elongated muscular tube** lying along **mid dorsal line** of thorax and abdomen.
- It is differentiated into **13 funnel shaped chambers with ostia** on either side.
- The **first chamber** forms a single narrow tubular anterior aorta leading into the head sinuses. At the posterior end of each chamber, a pair of apertures (**ostia**) are present laterally.
- Heart receives blood from the pericardial sinus through ostia, which are guarded by **auricular valves** to check the flow of blood from the heart to the pericardial sinus.
- All the chambers of the heart are inter-connected and their openings are guarded by the **ventricular valves**, to allow the blood flow anteriorly only.



Open circulatory system of cockroach

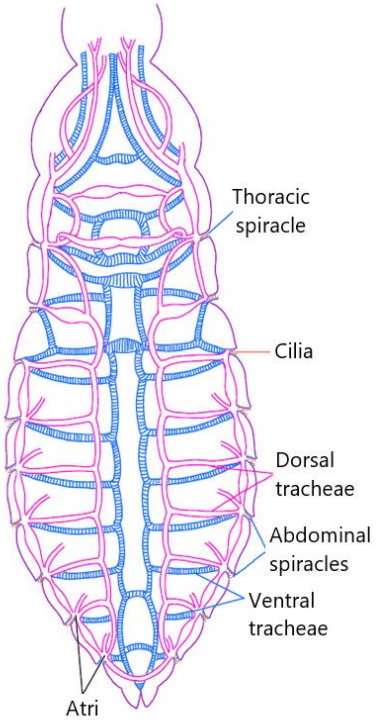


Diagrammatic representation of the working of valves in the heart

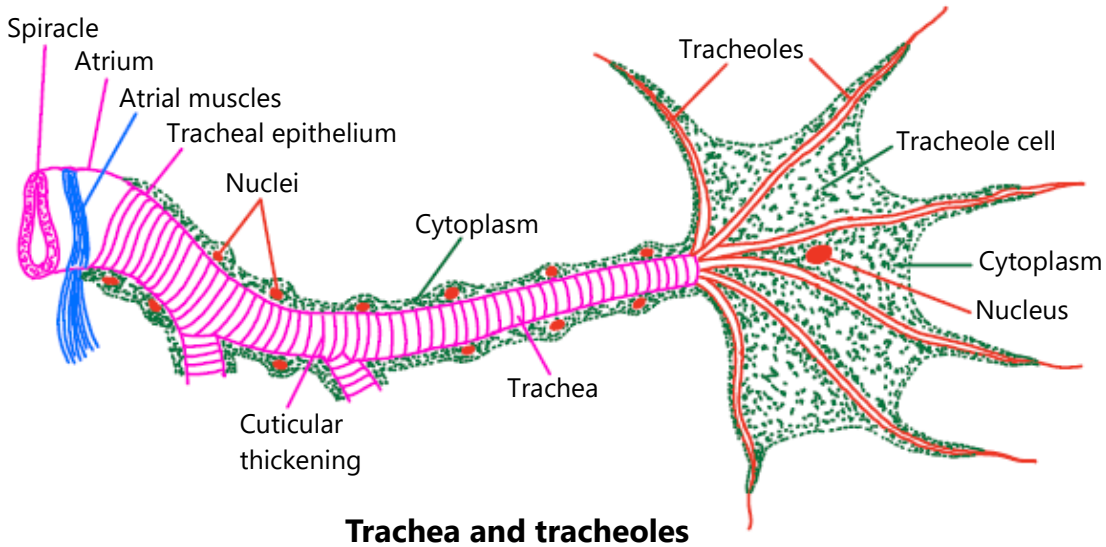
- The **last chamber** is closed posteriorly.
- Heart of cockroach is **neurogenic** (heart beat is initiated by a nerve impulse).
- Blood from sinuses enter heart through ostia and is pumped anteriorly to sinuses again.
- There are present **twelve pairs** of fan shaped and triangular **alary muscles**, their narrow ends are inserted into terga, while their broader ends are attached to dorsal diaphragm. The contractile alary muscles play a significant role in the blood flow from the heart to other haemocoelic spaces in blood circulation.

RESPIRATORY SYSTEM :

- The respiratory system consists of a network of **trachea**, that open through **10 pairs** of small holes called **spiracles** present on the lateral side of the body.
- **First two pairs** are known as **thoracic spiracles** and remaining **8 pairs** are called **abdominal spiracles**.
- Each spiracle is surrounded by annular sclerite (**peritreme**), which leads into chamber (**atrium**).
- Thin branching tubes **(tracheal tubes subdivided into tracheoles)** carry oxygen from the air to all the parts. The opening of the spiracles is regulated by the **sphincters**.
- **Tergo-sternal muscles** play an important role during inspiration and expiration.
- Exchange of gases take place at the tracheoles by diffusion.



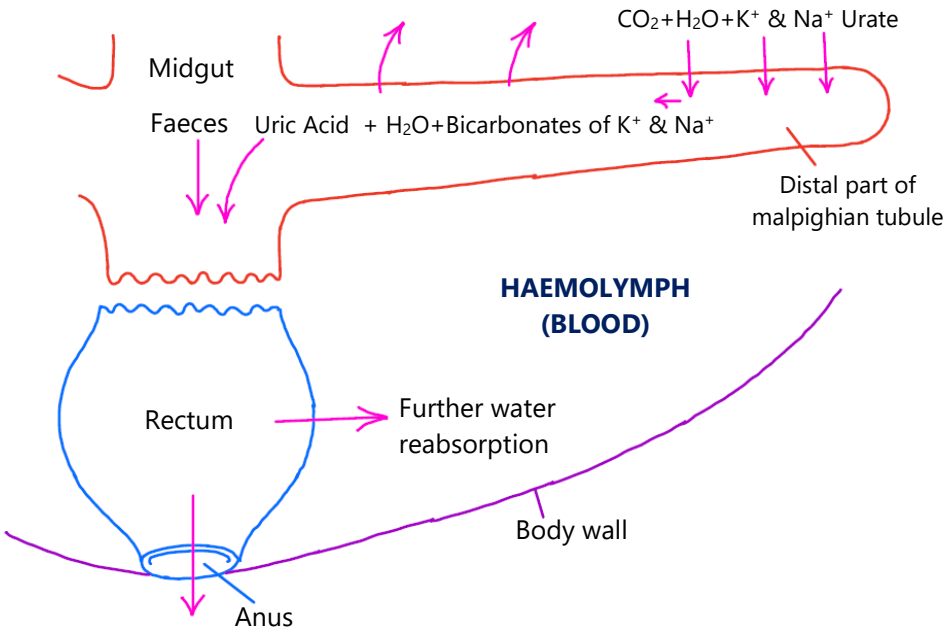
Tracheal system in cockroach



Trachea and tracheoles

EXCRETORY SYSTEM :

- Excretion is performed by **Malpighian tubules** (**100-150 yellow coloured**) which are present at the junction of midgut and hindgut. Each tubule is lined by glandular and ciliated cells.
- They absorb nitrogenous waste products and convert them into uric acid which is excreted out through the hindgut.



Excretion by Malpighian tubule

- Therefore, this insect is called **uricotelic**.
- In addition, the **Fat body, Nephrocytes** (*pericardial cells*) and **Uricose glands** (mushroom gland) also help in excretion.
- Fat body is functionally analogous to the liver of vertebrates.

Question-1: Blood vessels are poorly developed and open into space known as ?

(1) Lymphocoel (2) Blood Cavity (3) Circulatory Cavity (4) Haemocoel

Answer: (4) Haemocoel

Question-2: Visceral organs located in the haemocoel -

(1) Supplied by blood vessels (2) Bathes directly in the haemocoel

(3) Do not need any circulatory structure (4) Receives blood from ostia

Answer: (1) Bathes directly in the haemocoel

Question-3: Spiracles present on the which side of the body :-

(1) Dorsal side (2) Ventral side (3) Lateral side (4) Medially

Answer: (3) Lateral side

Question-4: On the basis of nature of excretory products, cockroaches are :-

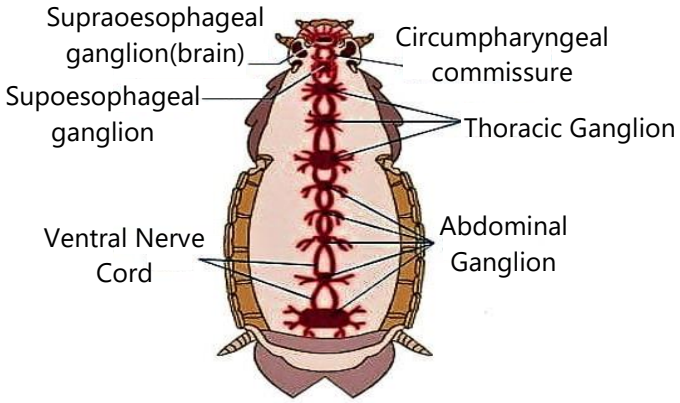
(1) Ammonotelic (2) Uricotelic (3) Ureotelic (4) Guanotelic

Answer: (2) Uricotelic

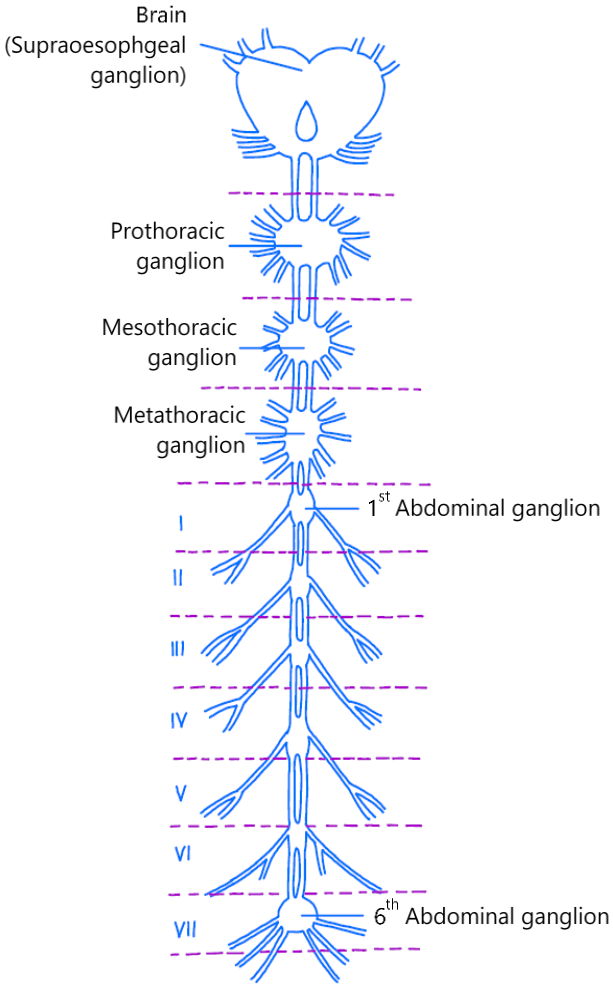
ANATOMY :

NERVOUS SYSTEM :

- The nervous system of cockroach consists of a series of fused, segmentally arranged **ganglia** joined by paired **longitudinal connectives** on the ventral side.



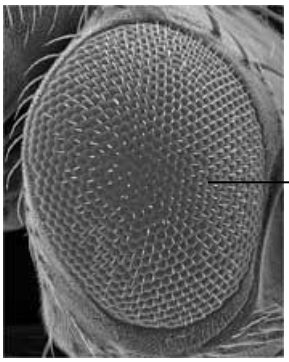
- **Three ganglia** lie in the **thorax**, and **six** in the **abdomen**.
- The nervous system of cockroach is spread throughout the body.
- The **head holds a bit of a nervous system** while the rest is situated along the ventral (belly-side) part of its body. **So, now you understand that if the head of a**

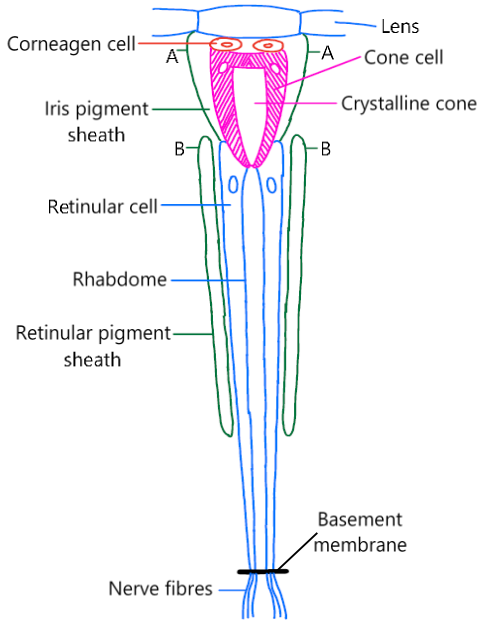


Central and peripheral nervous systems of cockroach

cockroach is cut off, it will still live for as long as one week.

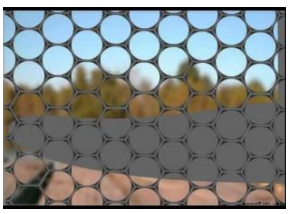
- In the head region, the brain is represented by **supra-oesophageal ganglion** which supplies nerves to antennae and compound eyes.
- In cockroach, the **sense organs** are **antennae, eyes, maxillary palps, labial palps, anal cerci, etc**.
- The **compound eyes** are situated at the dorsal surface of the head.
- Each eye consists of about **2000** hexagonal **ommatidia** (sing.: *ommatidium*). With the help of several ommatidia, a cockroach can receive several images of an object.
- An **ommatidium** consists of two parts :- **(i) Diopteric (ii) Receptive**
- **Diopteric part** is meant for focussing light rays coming from an object.
- **Receptive part** converts the image into an impulse which is conveyed to the brain.
- The diopteric part consists of **corneal lens**, 2 **corneagen cells**, a **crystalline cone** and 4 **cone cells** (**vitrellae**).
- Cone cells are surrounded by **iris pigment sheath**.
- Receptive part is made of spindle shaped **rhabdome** secreted by 8 **retinular cells** (**retinulae**).





V.S. of an ommatidium

- This kind of vision is known as **mosaic vision** with **more sensitivity** but **less resolution**, being common during night (hence called **nocturnal vision**).



Mosaic Vision

- The **ocellae** or **fenestrae** or **ocellar spots** located near the compound eyes are regarded **undeveloped simple eyes** by some and functional by others because they are **sensitive to light**.

Question-1: The type of vision present in cockroach is –

(1) Photopic vision (2) Coloured vision (3) Binocular vision (4) Mosaic vision

Answer: (4) A

Question-2: Antennae of cockroach function as-

(1) Tactile, olfactory, thermal and gustatory receptor
(2) Only tactile and Auditory
(3) Only Auditory, Olfactory
(4) Only Auditory receptor

Answer: (4) A

Question-3: Which of the following is not a sensory organ in cockroach?

(1) Antennae (2) Wings (3) Maxillary palps (4) Anal cerci

Answer: (2) Wings

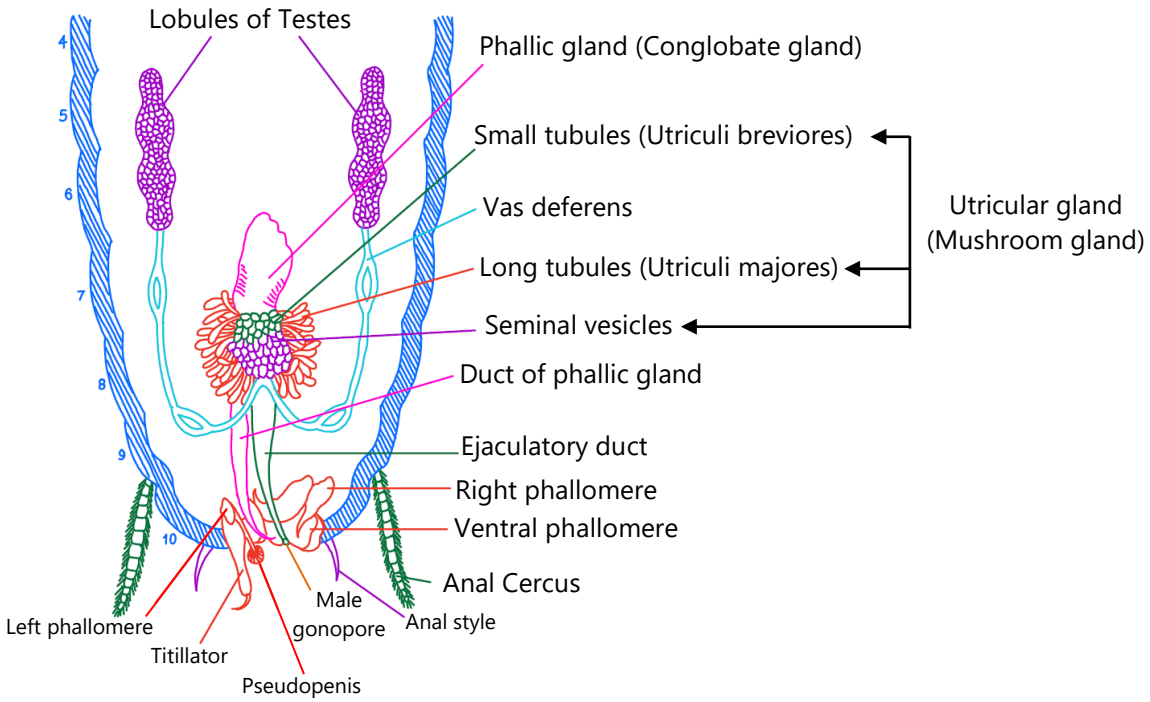
ANATOMY :

REPRODUCTIVE SYSTEM :

Cockroaches are **dioecious** and both sexes have well developed reproductive organs.

MALE REPRODUCTIVE SYSTEM :

- Male reproductive system consists of a **pair of testes** one lying on each lateral side in the **4th -6th abdominal segments**. Each testis consists of 3 or 4 interconnected lobes.



Reproductive organs of male cockroach

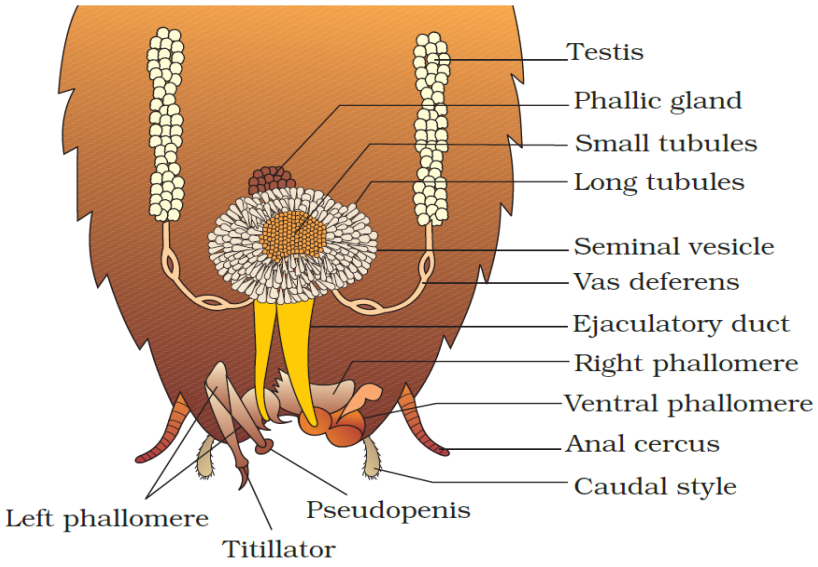
- From each testis arises a thin **vas deferens**, which opens into **ejaculatory duct** through **seminal vesicle**.
- The ejaculatory duct opens into **male gonopore** situated **ventral to anus**.

- A characteristic **mushroom shaped gland (Utricular gland)** is present in the **6th-7th abdominal segments** which functions as an accessory reproductive gland. It is formed of 3 types of small sac-like tubules :-

  (i) long tubules or **utriculi majores**

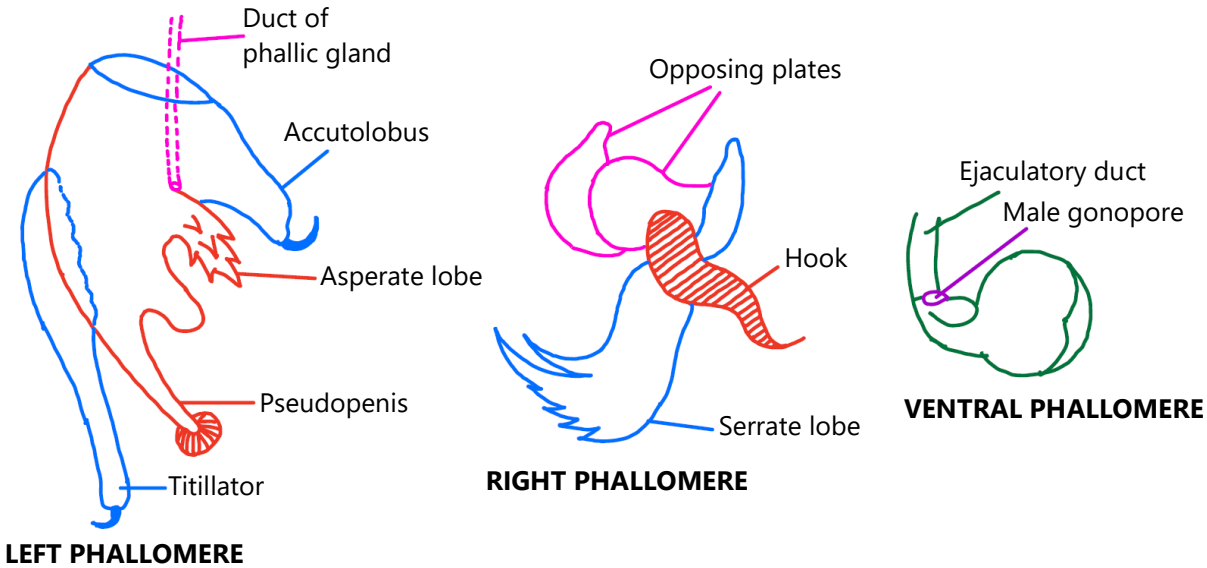
  (ii) small tubules or **utriculi breviores**

  (iii) **seminal vesicles**



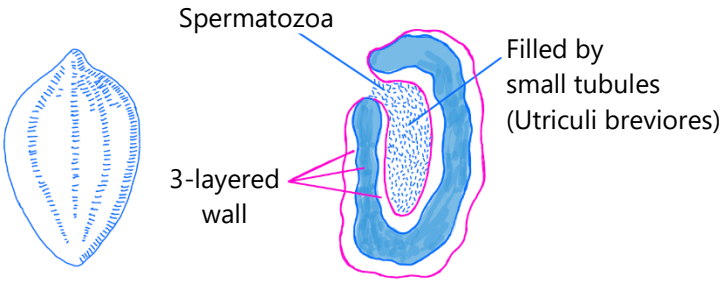
Male Reproductive System

- **Phallic** or **Conglobate** gland is a long, flattened, club-shaped accessory gland, located ventrally beneath the utricular gland.
- The **external genitalia** are represented by **male gonapophyses** or **phallomeres** (3 asymmetrical chitinous asymmetrical structures - **(i) Right phallomere (ii) Left phallomere (iii) Ventral phallomere)**. These genitalia surround the male gonopore.



Male gonapophyses or phallomeres

- Mature sperms are conducted by vasa deferentia from the testes into the seminal vesicles. All sperms of a seminal vesicle are glued together into a large mass called **spermatophores**, males discharge spermatophores during copulation. During its discharge, spermatophore becomes invested by a covering formed by milky secretion of long tubules (utriculi majores). This covering gives a pouch-like shape to spermatophore with a small aperture on one side.



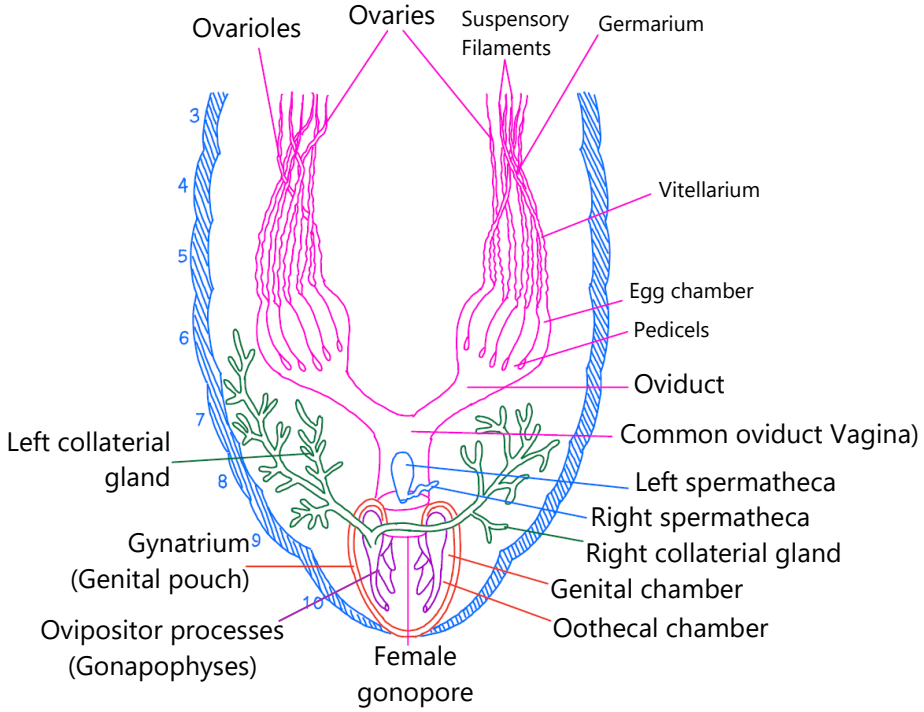
Spermatophore and its L.S.

- The secretion of small tubules (utriculi breviores) fills into the spermatophore and nourishes the sperms.
- As the spermatophore reaches at about the middle of ejaculatory duct, it becomes invested by a second converting formed by the secretion of the wall of ejaculatory duct.
- Finally, as copulation concludes, spermatophore is discharge, it becomes invested by a third covering formed by the secretion of phallic gland poured upon it.

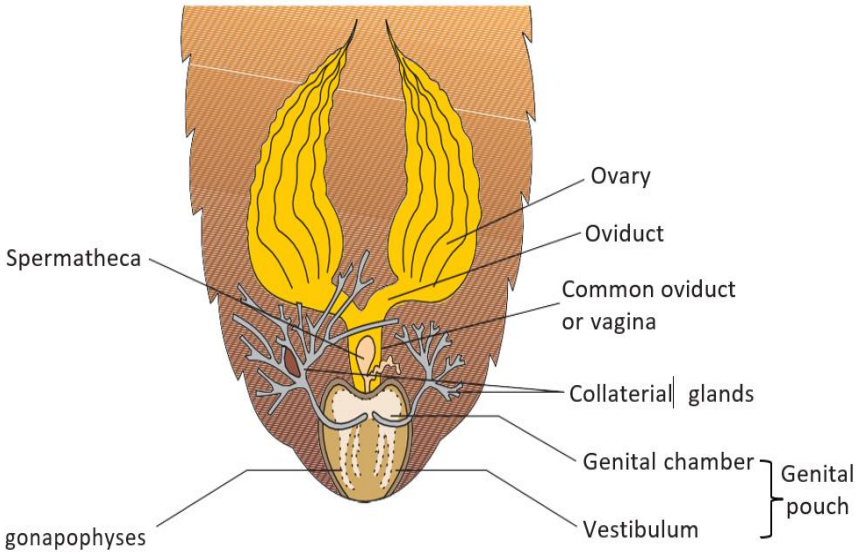
FEMALE REPRODUCTIVE SYSTEM :-

- The female reproductive system consists of **two large ovaries**, lying laterally in the **2nd – 6th abdominal segments**. Each ovary is formed of a group of **eight ovarian tubules** or **ovarioles**, containing a chain of developing ova. Each ovariole consists of :-

(i) Suspensory filament **(ii) Germarium** **(iii) Vitellarium** **(iv) Egg chamber**
(v) Pedicel

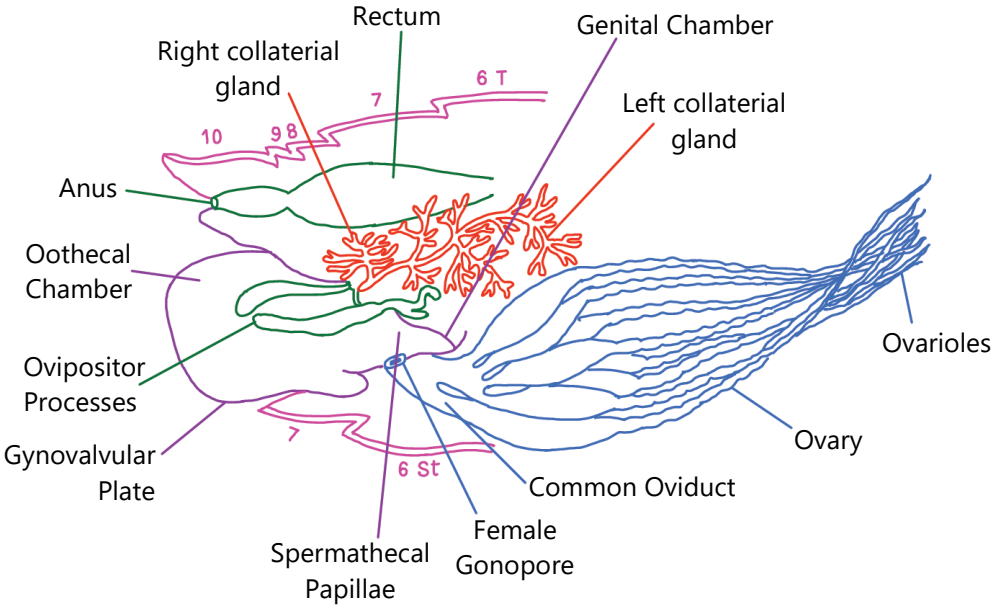


Reproductive organs of female cockroach



Female Reproductive System

- **Oviducts** of each ovary unite into a **single median oviduct** (also called **vagina**) which opens into the **genital chamber (gynatrium)**.
- Becoming broad and boat-shaped, 7th sternite forms the floor of a large **genital pouch**. The 8th and 9th sternites become **telescoped** inwards to form the roof and sides of this pouch. The pouch itself is divisible into a **genital chamber** in front and **oothecal chamber** behind. The vagina and ducts of accessory reproductive glands open into the genital chamber. The posterior part of 7th sternite is divided into two large and oval **gynovalvular plates** or **apical lobes**.
- **Collaterial glands** are a pair of white and highly branched accessory reproductive glands located dorsally to the genital pouch. The left gland is larger and more opaque than the right one. The secretions of these two glands also differ.
- **Spermathecae** are a pair of small structures located close to the collaterial glands.

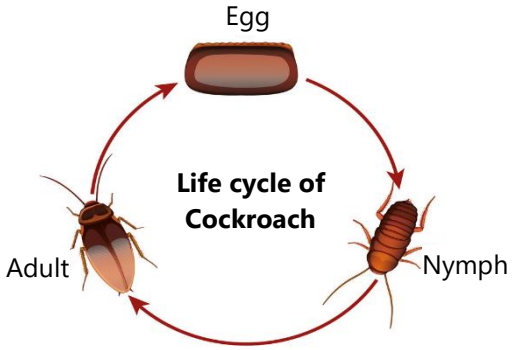


Reproductive organs of female Cockroach

- Female cockroach has **3 pairs** of chitinous **external genitalia** or **gonapophyses**, hanging from the roof of oothecal chamber into its cavity. These are also called **ovipositor processes**, because these serve to arrange the ova in a newly forming ootheca, and possibly help in giving proper shape to the oothecae.
- Fertilisation is internal, it occurs in the genital pouch of females. **Eggs of cockroach are centrolecithal.**
- **Fertilised eggs are encased** in **capsules** called **ootheca**. Ootheca is a dark reddish to blackish brown capsule, about 3/8" (8 mm) long. **Oothecae** are formed in the oothecal chamber. On an average, females produce **9-10 oothecae**, each containing **14-16 eggs**. Formation of an ootheca takes about 20 hours. Eventually, the female deposits oothecae in some dark and dry place.
- The development of *P. Americana* is **paurometabolous**, meaning there is **development through nymphal stage**.
- The nymphs look very much like adults. The nymph condition persists for about 6 months to 2 years.

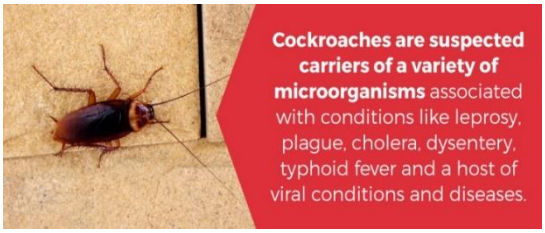
Nymph

- The nymph grows by **moulting about 13 times** to reach the adult form. Ecdysone or moulting hormone initiates the process of moulting, it is secreted by prothoracic gland. These glands degenerate after metamorphosis.
- The next to **last nymphal stage has wing pads** but only **adult cockroaches have wings**.



- Many species of cockroaches are wild and are of no known economic importance yet.
- A few species thrive in and around human habitat.
- They are pests because they spoil food and contaminate it with their smelly excreta.

- They can transmit a variety of bacterial diseases by contaminating food material.


Cockroaches are suspected carriers of a variety of microorganisms associated with conditions like leprosy, plague, cholera, dysentery, typhoid fever and a host of viral conditions and diseases.

Question-1: Find out the incorrect pair w.r.t. cockroach:–

(5) A pair of testis - 4th - 6th abdominal segments
(6) Mushroom gland - 6th - 7th abdominal segments
(7) Titillator - Left phallomere
(8) Innermost layer of spermatophore - Utriculi brevivores

Answer: (4) Innermost layer of spermatophore - Utriculi brevivores

Question-2: Collaterial glands of cockroach help in:-

(1) Fertilization
(2) Formation of ootheca
(3) Copulation
(4) Formation of oothecal chamber

Answer: (2) Formation of ootheca

Question-3: Main character for the distinction between male and female cockroach is:-

(1) Antennae
(2) Mandibles
(3) Anal cerci
(4) Anal Style

Answer: (4) Anal Style